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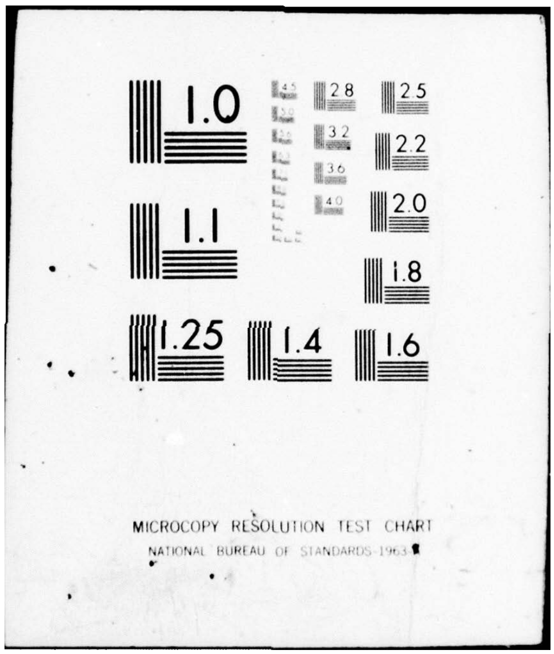
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# ENVIRONMENTAL PLANNING IN DOD

Edited by

Lt Col Patrick J. Sweeney, MS, PE
School of Systems and Logistics
Air Force Institute of Technology





JANUARY
1977

*To Kay*

## ACKNOWLEDGEMENTS

My first acknowledgment is to Lt Col Edward J. Fisher, Ph.D., who as a teacher, friend, and colleague has been a source of inspiration and encouragement in this and other professional endeavors. I am also indebted to all of my students, who have made teaching such a satisfying experience. In preparing this text, a large amount of available information was screened, analyzed, and reduced into a form believed to be most useful to the reader. Contributions are gratefully acknowledged from many of my students and friends and include papers from Capt A. W. Oltyan, Capt L. W. Laugginger, Capt R. T. Williams, Capt L. Schmidt, Capt W. D. McDermott, Mr. G. Flottman, Capt T. P. Cormany, Capt A. K. Bean, Mr. J. P. Donnellan, Capt W. G. Berry, Jr., Mr. W. H. Elbinger, Capt M. F. Nahlen, Capt W. W. Whittenberger, Maj J. H. Lowry, Maj R. O. Graf, Capt J. H. Cox, Jr., Maj F. S. Gersh, Maj T. L. Brown, Capt J. C. Nicholson, Capt J. C. Larson, Jr., Capt W. R. Harris, and Capt D. O. Burk.

Finally, but by no means last, I must express my appreciation to Mrs. Carletta Clemmer, Mrs. Wanda Adkins, Mrs. Kathryn R. Atkins, Renita M. Rapp, and Mrs. Betty J. Nelson, who typed and proofed this book.

WPAFB, Ohio
16 Dec 1976 P. J. Sweeney

# PREFACE

During the first half of the present decade, the American people became aware of the effects of environmental degradation on our quality of life. These problems, coupled with the current energy crisis, seem to present Americans with the proverbial choice between the rock and a hard place. We must clean up the environment, but that requires energy and energy production causes environmental degradation. Military managers must cope with the dilemma within the guidelines as promulgated by federal law, Defense Department, and the individual service regulations. My purpose in compiling these articles is to make available to students and Defense Department managers a work on environmental planning that would be suitable as an introductory graduate level text in the subject as well as a reference work for some more advanced study. The choice of subject matter is the editor's alone and reflects his perception as to subjects that will be most useful to those military decision makers and planners of our future living and working environments.

The work is divided into ten chapters with the first five devoted to providing the student with the necessary background in the traditional environmental topics. The second half of the book could be considered the application or implementation portion and includes, for example, chapters on law, OSHA, and cost/benefit ratio evaluations.

Chapter I deals with the concepts of ecosystems and population. A basic understanding of the effects of imbalances, the predator and the hunted relationships, and the niche concept are developed in this chapter. The problems of population explosion and/or control and how this significant factor impacts on the entire world is discussed.

Chapters II through IV cover the basics of air, water, and solid waste pollution and control. Energy, both nuclear and non-nuclear, is the subject of Chapter V.

With the above background, the student should be able to cope with the environmental issues he may face in the future. However, all solutions must be permitted by law and in consonance with DOD policy directives. Therefore, Chapter VI explains the current environmental laws and policies.

Few texts devoted primarily to environmental issues contain any reference to the working environment, and yet most of us spend great portions of life time on the job. The government is particularly concerned with working situations and in 1970, passed the Occupational Safety and Health Act. This law and the appropriate executive orders are covered in Chapter VII.

Probably the most important portion of the National Environmental Policy Act of 1970 concerns the protection of the quality of life of the American public by use of the environmental impact statement. Chapter VII describes what can happen and what should be done when decisions affect the government and/or the private sector. In the past, most decisions that affected the public sector were justified by using a cost/benefit model. This is still a valid approach to decision making and it is included in Chapter IX along with several examples of current decision models. Since this text was primarily compiled for defense department managers, it seemed appropriate to include the environmental degradation of waging war. The effects of bombing and herbicide spraying are included in Chapter X.

The references at the end of each chapter will, it is hoped, be a helpful guide for those who wish to do further study in this fascinating area.

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## TABLE OF CONTENTS

# CHAPTER I — ECOSYSTEMS & POPULATION

## ECOSYSTEMS

By Andrew W. Oltyan, Capt, USAF

### *Ecosystems*

The word ecology is derived from two greek words; ekos, which means the house, and logos, the knowledge of. Ecology then is the science dealing with the study or knowledge of man's house, the planet earth. Specifically, ecology can deal with the earth as a single system, or any subsystem.

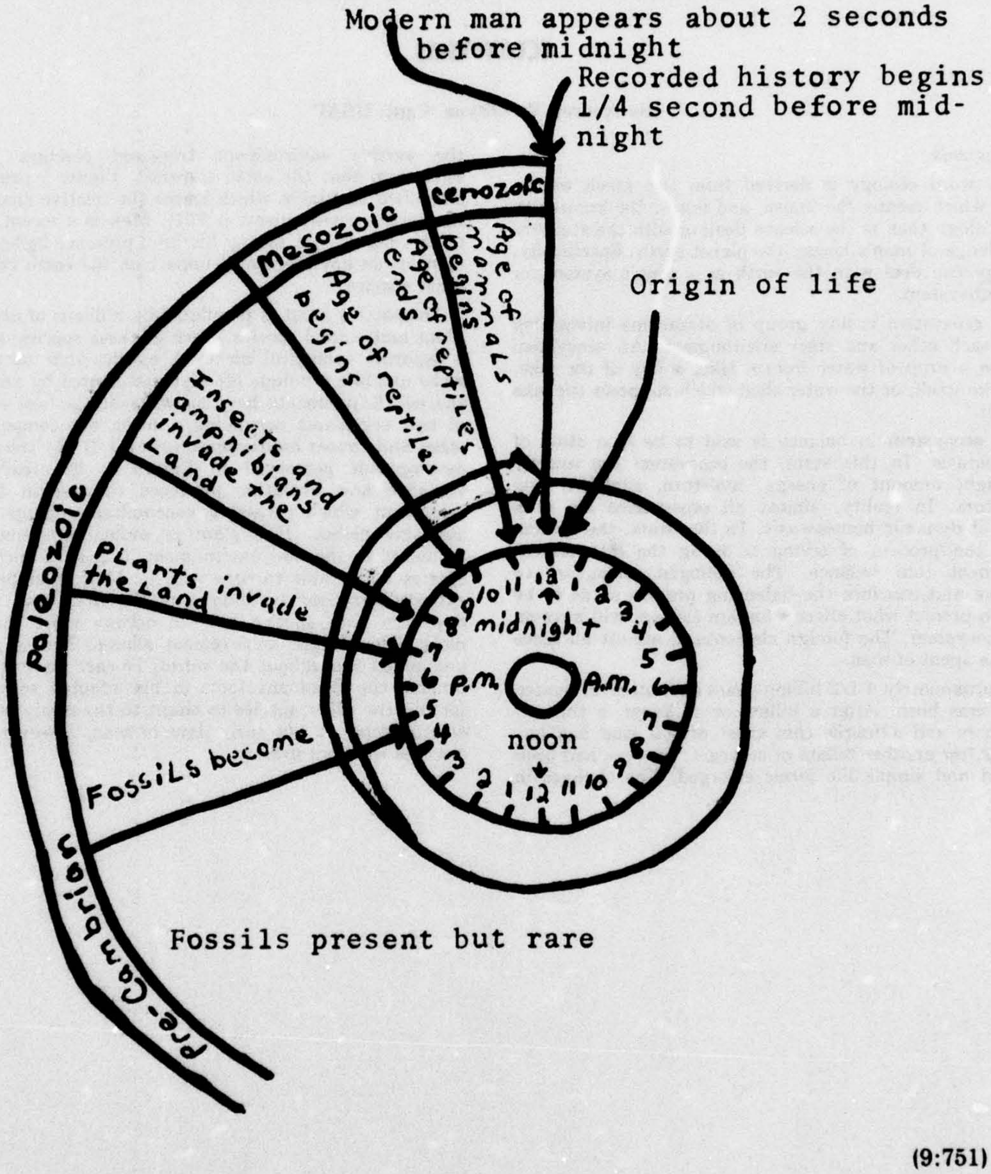
An ecosystem is any group of organisms interacting with each other and their environment. An ecosystem can be a drop of water from a lake, a bay of the lake, the lake itself, or the water shed which supports the lake (11:50).

An ecosystem in balance is said to be in a state of homeostasis. In this state, the ecosystem has exactly the right amount of energy, moisture, sunlight, and predators. In reality, almost all ecosystems are in a state of dynamic homeostasis. In this state, the system is in the process of trying to bring the internal environment into balance. The ecologist endeavors to observe and measure the balancing process so as to be able to predict what effect a foreign element will have on the ecosystem. The foreign elements in almost all cases are the agent of man.

Approximately 4-1/2 billion years ago, an arrid molten earth was born. After a billion or so years, a thin atmosphere and a fragile thin crust of soil land had formed. After another billion or so years, the seas had been formed and simple life forms emerged. The changes in the earth's environment triggered changes in the ecosystem that the earth spawned. Figure 1 presents a simplified timetable which traces the relative changes in the earth's environment (9:751). Man is a recent arrival to this planet, yet during his brief presence he has made more of an environmental impact on the earth than any other species.

The earth's crust is populated by millions of divergent plant and animal species. Each of these species occupies a separate ecological niche. A species that occupies a niche exhibits a unique life style not shared by any other species. Experiments have shown that the best adapted of two organisms occupying a niche out competes the other and causes its disappearance (11:7). By tracing the development portrayed in Figure 1, the reader can visualize how evolution produced changes in the environment which caused a concomitant change in the available niches. If a plant or animal was unable to acclimate to the new environment, it lost its niche to a species better able to cope with it. Man, equipped with extraordinary survivability was the first, and to this day, the only species able to occupy more than one niche. This unique achievement allowed him to wander unchecked throughout the world. In each ecosystem, he became the dominant force in his adopted ecosystem, forcing the other species to adopt to the newly modified environment. In the early days of man, however, these changes were not drastic.

THE HISTORY OF LIFE ON A 24-HOUR SCALE




(9:751)

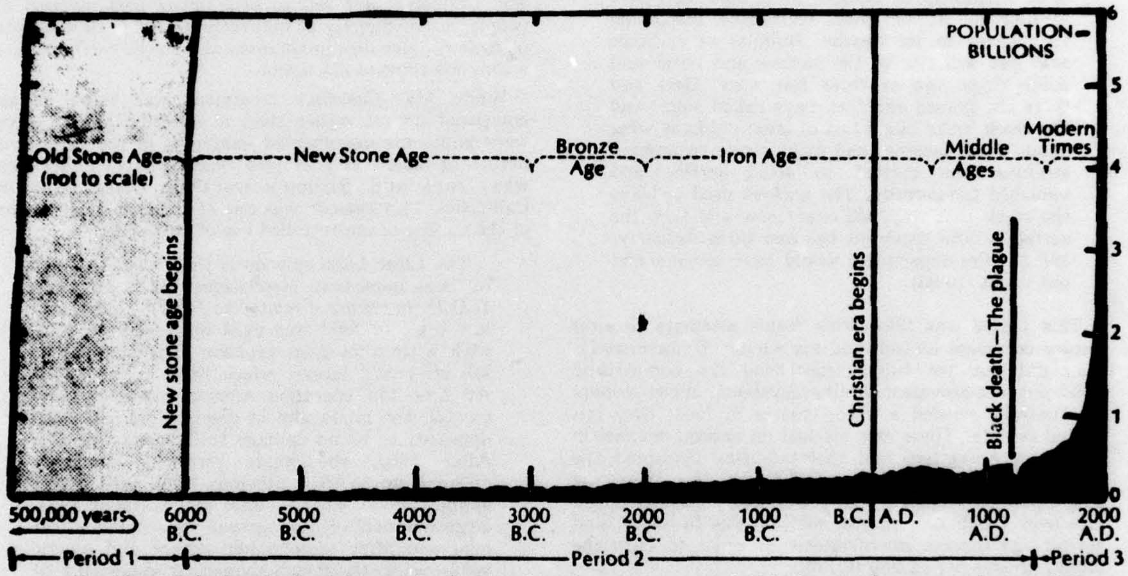
**Figure 1**

**Fossilized remains have helped to paint a fairly accurate picture of this prehistoric man. A hunter who used fire, lived in a land inhabited by many large aggressive mammals; great cats, bears, wolves, etc. Man, however, dominated them all and his dominance of this particular niche resulted in the extermination of many species (8:289). This was a natural occurrence which was duplicated by thousands of other species. The unusual part was man's dominance and mobility throughout several different niches.**

**Some 15 or 20,000 years ago Asiatic men migrated into the New World to populate both North and South America. As they became more proficient with tools, they learned to make both clothes and dwellings. These abilities further widened the spectrum of niches man was able to occupy. He was able to leave the tropical and subtropical lands from which he had evolved. Man spread north and south as well as laterally, and even learned to live comfortably in the polar regions (8:280-290). Even at this point, man was merely a successful**

competitor who simply out competed less adaptable predators for their niche. As a consequence the wooly mammoth, saber tooth tiger, and giant cave bear, to name a few, faded into extinction. This was in keeping with the normal evolutionary process by which the species gaining dominance by competition occupies the niche. Man was a part of the ecosystem he occupied and played the part of top predator.

GROWTH OF HUMAN NUMBERS




It has taken all the hundreds of thousands of years of man's existence on earth for his numbers to reach three billion. But in only 40 more years population will grow to six billion, if current growth rates remain unchanged. If the Old Stone Age were in scale, its base line would extend 35 feet to the left!

(5:143)

**Figure 2**

About five thousand years ago, man learned to use metals and entered the bronze age. Now man's development progresses rapidly. The use of metals allowed man to begin to change his environment to suit his purpose. He now created a more favorable niche for himself without regard for the consequences which the other inhabitants of the ecosystem had to face. It is at this point that man makes the transition from a participating member of an ecosystem to creator of an environment.

Until rather recent times, this is where man stayed. As the creator of his environment, he took action only when he could perceive some change in the environment would benefit him. Unaware of his membership in an ecosystem, he was not able to perceive the long range results of the modification of this environment. The relationship between the location of a privy next to a well and a resultant case of cholera was beyond man's scope in these early times. While this condition was widespread until the mid-20th century, it was not universal. There are several examples where ecosystems dominated by man have endured for long periods of time. The most prominent example of such an ecosystem can be found in Japan. Here man has sustained an intense agricultural production for thousands of years. The land has not been impoverished, but enriched by human intervention. The result has been the creation of a new stable ecosystem where the wild lands are balanced by the farm lands in a subtle harmony (3:47).

The dawn of the industrial era signaled a rapid acceleration of man's assault upon his ecosystem. This assault was different than his previous disturbances in both magnitude and degree. Figure 2 depicts the rapid population growth that paralleled the industrial revolution (5:143). This large population occupied more space and thus affected the environment to a greater extent. Coupled to this increase in population was the development of a technology which provided the means for disturbing the ecosystems at many different levels. Whereas before the environment could effectively cleanse itself, after a fashion, it was now subjected to such massive and traumatic changes that entirely new and sterile environments were created. Upton Sinclaire pictures such a transformation in his study of life in Chicago at the turn of the century.

> Bubbly Creek is an arm of the Chicago River, and forms the southern boundary of the yards; all the drainage of the square mile of packing-houses empties into it, so that it is really a great open sewer a hundred or two feet wide. One long arm of it is blind, and the filth stays there forever and a day. The grease and chemicals that are poured into it undergo all sorts of strange transformations, which are the cause of its name; it is constantly in motion, as if huge fish were feeding in it, or great leviathans disporting themselves in its depths. Bubbles of carbonic acid gas will rise to the surface and burst and make rings two or three feet wide. Here and there the grease and filth have caked solid, and the creek looks like a bed of lava; chickens walk about on it, feeding, and many times an unwary stranger has started to stroll across, and vanished temporarily. The packers used to leave the creek that way, till every now and then the surface would catch on fire and burn furiously, and the fire department would have to come and put it out (10:92).

This period was filled with man's attempts to alter nature to please himself and his whims. Unfortunately, man did not yet fully comprehend the homeostatic balancing act prevalent in all ecosystems. When settlers in Australia needed a cheap source of food, they imported rabbits. These animals had no natural enemies in their new ecosystem and their addition disrupted the carefully balanced ecology of the area. By 1950, the single pair introduced in the 19th century had multiplied into over 7 billion. The final solution was to import and spread the disease myxomatosis in order to curb the unmanageable population (6:120).

Another example was the importation of the water hyacinth to the United States. This decorative plant was first introduced to Americans during the Cotton Exposition of 1884. Many visitors were taken by the beauty of the plant and cuttings were started in many private residences. These cuttings eventually escaped into the adjacent environments where it found fertile grounds for survival. The result was unchecked growth which has rendered previously unencumbered waterways impassable (6:120-4).

As transportation and technological capabilities increased, a ready vehicle for the transportation of many divergent species was created. Man provided free rides for numerous spores, insects, plants, and animals. The dutch elm beetle, European citrus fly, Mexican fire ant, gypsy moth and common starling are just a very few of the unwanted visitors transported to the United States by man. These new species arrived and found an unoccupied niche, coupled with a lack of predators which had kept them in check in their previous ecosystems. Nature does not react very rapidly in these cases. While the 3 or 4 hundred years it usually takes to balance things out is short in the long run, it seems entirely too long to most human observers.

Along with the importation of numerous unwanted species, man was also busily establishing himself as the master predator. Man began a systematic campaign to eliminate his competition. Previously well established species such as the American bison and the grizzly bear were slaughtered to the point of extinction.

The cumulative effect of these man-made dilemmas was a drastic change to the overall environment. New niches were created and old ones changed hands. At last the magnitude of these changes became apparent and a movement arose to prevent destruction of the environment.

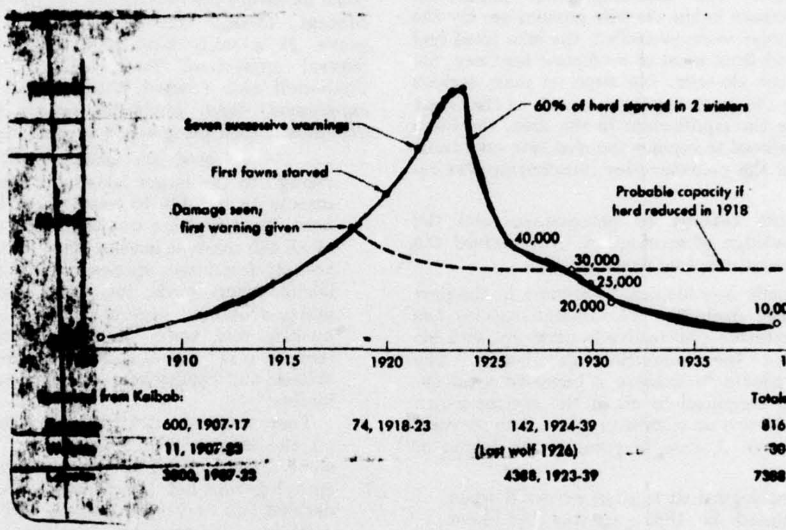
The science of ecology was first given substance in the 1850s by the German biologist, Ernst Haeckel. The real impetus of the ecological movement, however, coincided with Rachel Carlson's publication of the *Silent Spring.* Ms. Carlson's best selling book introduced millions of people, either directly or indirectly, to the basic concepts of ecology. Her dire predictions of a sterile earth became a common topic of discussion.

While Ms. Carlson's treatment was more of an emotional appeal rather than a scientific study, there were numerous documented examples of the persistent nature of insecticides. A now classic study in this area was Hunt and Bishop's work on Clear Lake in California. This episode was one of the best illustrations of the danger of uncontrolled use of pesticides.

> The Clear Lake episode is the classic example of how persistent insecticides work. In 1949, D.D.D. (a chemical related to D.D.T., but rather less toxic to fish) was used in the lake to deal with a tiresome gnat problem. The aim was to kill off gnats' larvae, which lived in the water. At first the operation seemed extremely successful; the gnats almost disappeared and there appeared to be no damage to fish and wild life. After 1950, the gnats returned, gradually creeping up to their previous level, and further applications of D.D.D. were made. But in 1954, large numbers of dead grebes were found at the lake and after some public uproar and several years' work, the facts emerged. It appeared that even the first application of D.D.D. had affected the reproduction of the grebes; but the deaths were thought to be caused by the D.D.D. travelling up a food chain, from the plankton and other minute organisms in the lake, to fish, then to the grebes which fed on the fish. Each successive form of life that consumed the chemical concentrated it, so that eventually the grebes took in a killing dose. This case was a landmark in the pesticides controversy, although it is now known that fish usually obtain most of their pesticide residues from the water through their gills (2:154).

Another study involving the effects of pesticides on birds was begun by Dr. Norman Moore who in fact originated the whole study of pesticides and birds of prey. Dr. Moore started investigating birds of prey in 1962. The populations of certain predatory birds had declined dramatically since the late fifties and the birds' breeding-levels had been falling since the late forties. They studied, among others, the peregrine, the sparrowhawk, the barn owl, the golden eagle and the heron, and patiently built up a cast iron case against persistent pesticides. As with the grebes in California, it was via their food that the birds of prey were affected. They collected disturbing evidence to show that residues of D.D.T. or allied substances had strange effects on the birds' reproductive mechanisms. The calcium content of eggshells was reduced, so that the birds had great difficulty in incubating their eggs without breaking them. Certain species, notably the golden eagle, were consistently laying sterile eggs.

Both the Clear Lake and the Moore study dealt with attempts to understand the extent to which a foreign body disturbs the environment. These studies concentrated on the "domino" theories of ecology which try and explain the multifaceted dependence acting within an ecosystem. At about the same time these experiments were in effect, there were concurrent studies in predation. These studies were aimed at trying to understand the predator - prey relationship in an attempt to re-establish a dynamic homeostasis in previously disturbed environments. A vivid example of this is illustrated by the oscillation of the deer population of the Kaibab Plateau in Arizona.




(7:95)

**Figure 3**

Prior to 1907, the deer herd on the Kaibab Plateau, which consists of some 727,000 acres and is on the north side of the Grand Canyon in Arizona, numbered about 4000. In 1907, a bounty was placed on cougars, wolves, and coyotes—all natural predators of deer. Within 15 to 20 years, there was a substantial extirpation of these predators (over 8000) and a consequent and immediate irruption of the deer population. By 1918, the deer population had increased more than tenfold; the evident overbrowsing of the area brought the first of a series of warnings by competent investigators, none of which produced a much needed quick change in either the bounty policy or the policy dealing with deer removal. In the absence of predation by its natural predators (cougars, wolves, coyotes) or by man as a hunter, the herd reached 100,000 in 1924; in the absence of sufficient food, 60 percent of the herd died off in two successive winters (7:95).

Figure 3 presents a projected deer bearing capacity if the herd had been reduced prior to the over-browsing.

One of the leaders in the research aimed at explaining the prey-predator balance was the Russian biologist G. F. Gause. Dr. Gause studied the interaction of two ciliated protozoans, paramecium caudatum, which thrives well on yeast and bacteria and didinium nasutum, which thrives well on a diet of fresh paramecia. In the first of these experiments, five paramecia were introduced into a small test tube containing an oat medium conducive to bacteria growth. Two days later, three didinia were introduced. Three and four days later respectively, both the paramecium and didinium populations were entirely extinct. Variations in the time of introducing the predator and even in the size of container always produced the same results — the increase and decrease of prey was a phase ahead of the successive increase and decrease of the predator, and both prey and predator were eliminated. Gause then modified the uniform or homogeneous oat medium environment by introducing some sediment which, in effect, created what he called "refuges" where paramecia could hide. The simultaneous introduction of predator and prey is followed by continued increase of prey and extinction of the predator. From replicates of this study, Gause concluded that as the microism approaches the natural heterogeneous conditions found in nature, population control is subject to a multiplicity of causes. In this particular instance, their simple predator-prey relationship becomes complicated by their accident of a heterogeneous environment in which paramecia are not so readily caught (7:93-95).

The Gause experiments tend to support the theory of out of phase oscillations of interacting predator-prey populations. The practical application of this theory has helped Forest Service biologists restore a balanced environment to much of the forest land under their care. This may often be a lengthy and expensive process. For example, millions of dollars have been spent to try and restore a dynamic environment to the Great Lakes.

An artificial access to the Great Lakes was created in the early fifties by the completion of a series of locks

connecting the previously land locked lakes with the Atlantic. Two previously absent species immediately made the presence felt. These were the ale wife, a small boney herring-like fish, and the North Atlantic lamphrey, a parasitic relative of the shark. The ale wife population was at first kept in check by the native lake trout who profited by the new food source. Unfortunately, the lake trout population was seriously depleted by the lampreys who had established themselves in the area. The declining trout population allowed for an increase in the ale wife population. By the time the sea lampreys were controlled, the lake trout had all but disappeared from most of its former territory. On the other hand, the ale wife, free from its most serious predator, became the most populous species in the Great Lakes. To restore the equilibrium in the area, the Coho salmon was introduced to replace the now rare lake trout as a predator and the predator-prey relationship was re-established.

Armed with the concept of homeostasis and the rudimentary knowledge of ecosystems, we reversed the usual process of environmental destruction.

The progress made in ecological awareness in the past ten years has been dramatic. The human species has taken the first tentative step to live in harmony with his environment since the industrial age began. The technology is available to achieve a balanced vital environment that is beneficial to all of the species which inhabit it. There is also no reason to give up on severely damaged ecosystems. A case in point is the Island of Krakatoa.

> A drastic ecological disruption occurred when Krakatoa erupted in 1883. It was the most savage and powerful volcanic outbreak in history. The volcano's top blew up with a force equal to the explosion of a 10,000-kiloton atom bomb, and while it did not produce the radioactive fallout as such a bomb would, it did have a lethal effect. It eliminated all life in the area, with the possible exception of a few roots, fungi spores, or soil organisms in protected deep cracks of rock.
>
> Five cubic miles of rock, debris, and ash were flung as high as 90,000 feet into the air. The heat, lava, tidal wave and other destructive forces killed not only the 36,000 people on the island, but all other forms of life existing there — every animal and every plant. Even the tiny spores or floating seeds of vegetation were snuffed out. The island of Krakatoa had to start anew from a total biological vacuum. Yet in nine months, the first new living thing was spotted on Krakatoa — a spider, which must have been wafted across some twenty-five miles of open sea on a natural balloon of silken web. Airborn algae arrived next, and soon mosses, ferns, and flowering plants began to germinate in the rich seed bed as a variety of spores drifted onto the island. Seeds too heavy to float in the air drifted across the water and took root in new soil as it formed. Birds flew to the island and animals swam the distance.
>
> Eleven species of ferns and fifteen kinds of flowering plants were growing there within three years. Within twenty-five years, many more species of animals ranged the island. Most of these were insects that had flown across the water barrier, but there were also sixteen kinds of birds and two of reptiles and a number of land snails. Fifty years after Krakatoa blew its top, with total destruction of all life, it was again a lush paradise with a thick forest, a profusion of flowers, and more than 1,200 species of animals existing in a new ecological system (6:120-121).

This is an example of the natural power available to rejuvenate an ecosystem. It also seemed to indicate that given the proper environment, life will flourish much the same as before the destruction of that environment. This concept, though seemingly obvious, was difficult to prove. It is fairly hard to experiment with an entire natural ecosystem. Two Harvard Biologists, Daniel Simberloff and Edward Wilson, did however devise an experiment which would do exactly that. The Wilson experiment took place in the Florida keys. Here they,

> . . . . selected six islands, which were near enough to the larger islands or the mainland for insects to be able to reach them in large numbers. Their first act was to make a careful survey of all the resident insects. They found that about seventy-five insect species usually inhabited their island. Many birds, including green herons and white-crowned pigeon, visit the mangrove bushes, and water snakes and the occasional raccoon make use of them from time to time, but Wilson and Simberloff were concerned only with insects.
>
> They then set about systematically removing all the insects from the islands. It took them some time to find the best method. Chemical spraying was not 100 percent effective, so they decided to try fumigation, which involved erecting a reasonably airtight covering and puffing in gas. They tried various kinds of gas, because they needed one that was not soluble in water and would not harm the vegetation. They found that if they fumigated during daylight, even when the sun wasn't out (which down there it usually is), the extra heat severely damaged the mangroves, so in the end they decided to do all the fumigation at night.
>
> They fumigated the first island by using an elaborate scaffolding, which proved effective but clumsy. They eventually compromised with a steel tent-pole, erected high enough to take the weight of the canvas, which was winched up to the top of the pole and then carefully lowered and secured with sandbags and stakes below the water.
>
> They then killed off all the bugs and flies on the islands. To make absolutely certain that there were no survivors, they broke and examined literally thousands of hollow twigs, lifted or peeled off loose bits of dead bark, squirted mild insecticides beneath bark and into hollows to drive out stragglers, and dug into likely hiding places with a steel probe. All this work had to be done with great care to avoid damaging the insect habitats, which would have affected recolonization.
>
> For nearly nine months, they visited the islands every eighteen days, minutely observing the recolonization process. To ensure that they brought no insects with them when they visited the islands, they usually anchored their boats some way away, scrupulously examined their bodies and clothes for any lurking creatures, and

regularly sprayed themselves and their equipment

The insects began to return. Wilson and Simberloff noted the order in which the various insects arrived; the rate at which they settled and began to breed; and the method by which they made the journey. "Invasion", as the process is technically called, took place in a number of ways; the insects flew, swam, were carried by winds, and arrived via birds, as parasites, or concealed in twigs. Some came drifting in on rafts of floating vegetation. The air, which most people think of as "empty", is in fact thick with invisible or barely visible forms of insect life, "aerial plankton" as one early entomologist called it. Millions of these creatures circulate without finding a resting place and eventually die off.

After two hundred and fifty days, they found that all the islands except the most isolated one had been recolonized by almost exactly as many different species and in much the same proportions, as before—although the total number of insects was still relatively low (2:177-197).

The preceding illustrations indicate that, given an environment which is returned to a sterile natural state, a dynamic homeostasis will be naturally established. The niche will be filled by the most competitive species in approximately the same proportions they occur in similar environment. These findings support the contention that it is possible to return our planet to a naturally balanced ecosystem. It will not be the same environment we knew 1000 or even 100 years ago, but that is to be expected. Every ecosystem undergoes periodic cylical changes. Some species wane, others gain momentum. Competition for the available niches spawns reciprocating changes which may effect bordering ecosystems. The natural state is one of change where species die out and new ones are created. This is a normal healthy state. The dodo bird is extinct because it could not cope with a new predator The loss of this species did not seriously effect the rest of its environment. On the other hand, the eutrophication of Lake Erie will not cause the extinction of any species, but will drastically and negatively modify the adjacent ecosystems.

Each case should be considered in depth and on its own merits. There are no easy rules or pat formulas to predict the results of our present actions. Because this is true, it is necessary to examine each alternative solution and choose the safest, not the easiest. Constant assessment is required. As Justice William O. Douglas put it, "For things to change there must be a spiritual awakening. Our people - young and old must become truly activist - and aggressively so if we and the biosphere on which we depend are to survive. We can serve on that role only if we believe, with the Sioux, in the goodness and the beauty and the strangeness of the greening earth, the only mother (4:200)."

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# CHAPTER I — ECOSYSTEMS & POPULATION

## POPULATION

By Leon W. Laugginger, Capt, USAF

*Introduction*

We, the people, form what may be termed as a "closed" population on our planet. That is, there will not likely be any substantial movement of people to other planets much less other solar systems. In other words, our planet's population is "closed" or restricted to the limited physical dimensions of the earth on which we live.

Natural characteristics of any such "closed" population are that it will grow if the birth rate exceeds the death rate and it will shrink if the death rate is greater than the birth rate.

Recent technological advances have greatly enhanced man's ability to postpone his own death. Relative to past eras, man is now effectively practicing death control. Unfortunately, he has not been quite so effective in his quest to achieve a relative balance between his decreasing death rate and his increasing birth rate.

Our planet cannot support the present rate of population growth for any sustained period of time. The only alternatives are an effective and humane control of births on a world-wide basis or the natural, though cruel, equalizer of mass misery and death (6:13).

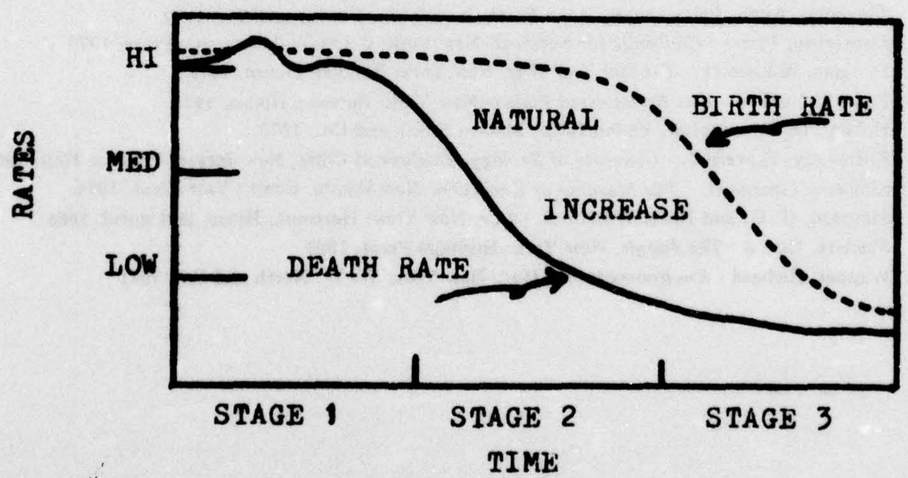
WORLD POPULATION

*AT PRESENT*

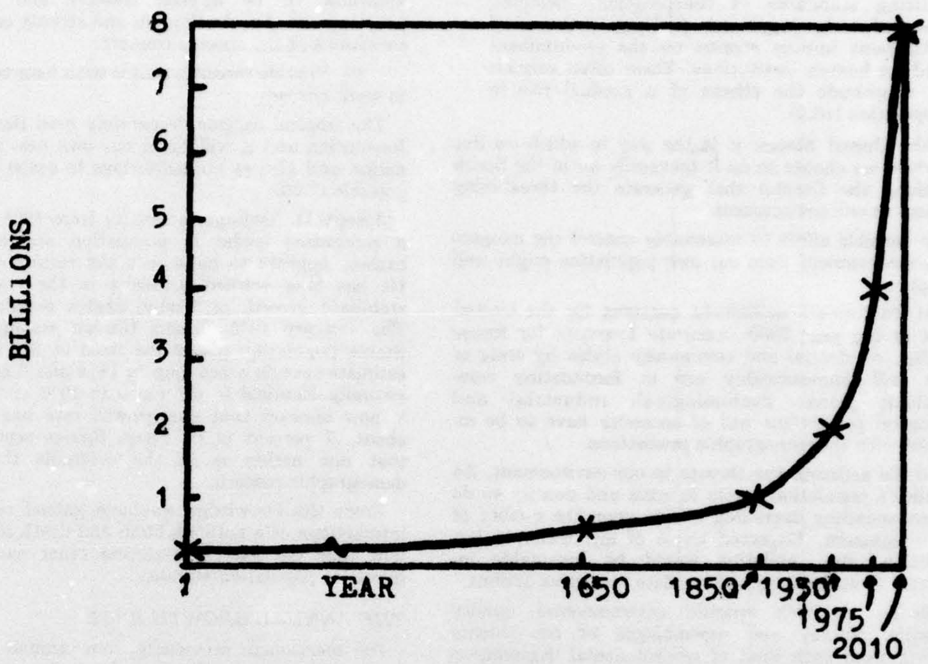
The total world population is obviously the sum of the populations of each of the countries. In turn, the population of each country can be viewed as following a pattern of demogaphic transition. Each particular country may be in any one of three stages of the transition as depicted in Figure 1 (6:44).

Stage one represents a popuation that has high but fluctuating birth and death rates. Such a population is either stable or slow in growing. In the second stage, the death rate declines more sharply than the birth rate, usually because of improved medicine and health care. This stage generates a rapid growth in population. The final stage is indicative of low and closely equal birth and death rates producing a population that is slow in growth or stable. At present, two-thirds of the world is in stages one and two of this demographic transition, explaining the world's population growth rate of approximately two percent (12:432).

The developing areas of Asia, Africa and Latin America can be generally classed into stage two of the transition pattern and have growth rates of two percent or higher while the developed areas of Europe, the United States and Russia boast growth rates of one percent or lower, placing them in stage three.




DEMOGRAPHIC TRANSITION
**Figure 1**




**POPULATION INCREASE**

**Figure 2**

**Reliable estimates now (1975) place the world's population at four billion (12:433). This figure is more than double the earth's population of just forty-five years ago.. The dramatic increase can basically be explained by a relatively constant or slightly increasing birth rate on a world-wide basis, but especially in the developing nations. Approximately ten thousand people are now dying per week from starvation across the earth as world population continues to rise unchecked (3:16).**

***PROJECTED***

**There is no infallible guide in projecting the growth of world population. A concensus of learned opinions indicates that the increase in numbers in the underdeveloped areas will be so great in the foreseeable future that no reasonably probable increase in labor and production techniques can prevent a rise in their death rates, unless these people learn to reduce their birth rates (11:984). The most formidable obstacles preventing the rapid spread of voluntary control of birth rates are cultural in nature. It is not likely that these obstacles will be easily, or even effectively, surmounted within the next two or three decades. Hence, the spiral of world population appears destined to continue with only minor checking actions provided by new technological advances.**

**Current projections, derived from United Nations estimates, have the world population once again doubling in just thirty-five short years to a total of eight billion souls by the year 2010. Figure 2 incorporates past, present and projected world population data for comparison purposes (12:432). A staggering statitic of note is that by the year 2000, India will have to build one new city of one million every thirty days to cope with its population growth and settlement patterns (2:1).**

***UNITED STATES POPULATION***

**The United States Census Bureau, in 1960, listed fifty-two Standard Metropolitan Statistical Areas (SMSA) whose populations exceeded half a million persons (9:v). These cities totalled approximately eighty million inhabitants or close to forty-five percent of the nation's populace at that time. Estimates are that these SMSA's will contain 124 million inhabitants by 1980. These projections imply an important geographical redistribution of metropolitan populations. It appears that more people are moving to the metropolitan areas, in particular those in the South and West. Eastern industrialized cities should continue to increase their populations, but a lesser rate than the nation's other large cities. There appears to be a slight to moderate trend towards urbanization of our populations. We are moving into metropolitan areas, but out of large cities (those of us who are able to do so).**

**The conviction that the United States contains, or will very shortly contain, absolutely too many people has proved to be short lived. Saner voices have shown us the realization that the absolute number of people is, for the United States, not a very pervasive threat to the integrity or the quality of our lives. Conrad Tasuber of the Census Bureau reflects this growing attitude when he says:**

> **"The population problems of the United States are and will be much more of geographical distribution and the way we use our resources than of the rate of increase in our total number (10:2)."**

**Peter Morrison of RAND is basically in agreement when he argues:**

"Rising standards of consumption, changing uses of technology and evolving patterns of settlement impose strains on the environment and on human institutions. These often surpass in magnitude the effects of a gradual rise in population (10:2)."

In the United States, it is the way in which we live and where we choose to do it (generally all in the South and along the Coasts) that generate the threatening problems to our environment.

Any sensible effort to reasonably control the dangers to our environment from our own population might well attempt:

(1) To forecast settlement patterns for the United States in the year 2000. Accurate forecasts for future densities, residential and community styles by state or region will immeasurably aid in formulating compensating plans. Technological, industrial and sociological predictions will of necessity have to be integrated with the demographic predictions.

(2) To estimate the threats to our environment. As a locality's population grows in scale and density so do the corresponding degrading effects upon the quality of the environment. Expected levels of air, water, noise, congestion, etc., pollution would be invaluable information in attempting to formulate corrective actions.

(3) To establish specific environmental quality standards. Survey and assemblages of the threats resulting from each kind of environmental degradation can yield tolerable and preferable limits, subject to constant re-evaluation, for each type of degradation.

(4) To identify and assess controlling policies. What policy would work best in which location and for what problem is largely a matter for intelligent speculation.

(5) To calculate and assess in some equitable manner the costs to be incurred in the implementation of selected policies. Where determinable, those who benefit should pay.

These have been only a few representative approaches to the identified problems facing the United States in relation to its population dispersal trends. Once again, it is not our numbers but our attitudes, life style, and choice of locality in which to live that presents us with our environmental problems. In contrast, the most pressing problem associated with world population is the absolute number and the direct problem of how to feed the masses.

The anatomy of the Green Revolution, which began in the United States back in the 1860's, suggests some ways and means by which we can deal with the genuinely crucial problems of food shortages in the underdeveloped nations of the world. Only five percent of our population supplies our country its food while in the tropical lands up to eighty percent of a country's population is required to work the land to supply its own food requirements. This is the Green Revolution and the developing countries must shift this ratio if they hope to ease their food shortage problems. By influence or direct assistance the United States might assist developing nations toward the realization of their own Green Revolution might be:

(1) Increase the training of agricultural specialists in the universities of the tropics.

(2) Assist each country with "adaptive research". This principle recognizes the inability of American knowhow to be applied directly and dictates the development of technology in and strictly catering to the conditions of the specific country.

(3) Provide research people with long-term contracts to work abroad.

The tropical nations desperately need their own Green Revolution and it will be in our own best interests as a nation and also as humanitarians to assist in every way possible (7:98).

Joseph D. Tydings, a senator from 1965 to 1971, and a recognized leader in population and environmental causes, appears to have seen the results of his labors. He has long worked to assist in the realization of a stabilized growth of United States population (8:131). The January 1975 Census Bureau estimate of United States population places the total at 213,203,059. This estimate reveals a net gain in 1974 of 1.6 million people, virtually identical to the gains in 1972 and 1973. Thus, it now appears that our growth rate has stabilized at about .7 percent (4:1). These figures seem to confirm that our nation is in the desirable third stage of demographic pattern.

From the knowledge we have gained relative to the interactions of a nation's birth and death rates, we must now take the lead in assisting other nations in their quest for population stability.

### *THE ANNUAL GROWTH RATE*

As mentioned previously, our annual growth rate appears to have stabilized at about .7 percent. This rate is determined by the following formula:

> Annual rate of growth=(birth rate - death rate)/10 where the birth and death rates represent the number of births and deaths per 1000 people/year.

Although some will still argue that zero percent growth is what is needed, a stable growth rate of .7 percent/year is an enviable national population position to enjoy. Contributing factors in the reduction of our birth rate, to mention a few, have been:

(1) increased incidence of voluntary sterilization.
(2) more liberalized abortion laws.
(3) improved mechanical and chemical contraceptives.
(4) emphasis on family planning services.
(5) mass education on the population "explosion".

Our declining death rate can be generally attributed to great gains in medical technology and improved health care nationwide. In 1870-1875, the annual birth rate was 40.8 per thousand and the annual death rate was 21.8 per thousand (5:189). Since that time, the rates have generally declined to approximately 16.3 and 9.3 respectively. Or relatively good standing in the world population arena certainly does not warrant complacency. So many factors are at work in the determination of a nation's growth rate, particularly involving its birth rate, that any number of unpredictable events could easily send the annual growth rate soaring in a relatively short period of time.

## CONCLUSIONS

We must be cautious in the use we make of our knowledge gained from past population changes because close association of conditions cannot usually serve as a proof of casual relationships. Such knowledge can only

serve to be merely suggestive of possible future changes.

The Western peoples, as a whole, have completed their transition through the period of their most rapid growth. The growth of developing countries seems now to be dependent upon how well they will be able to feed themselves. The natural (hardship) checks remain to be the only apparently successful limiting factors to the spiraling populations of those countries who have not yet made the transition from high and largely uncontrolled birth rates and death rates to low and controlled birth rates and death rates.

Population size is the keystone to environmental problems. Larger populations cn be indirectly equated to the quantity of pollutants and to the quality of our environment. Therefore, pollution of all types can be viewed as merely a symptom of an increasingly world-wide unsupportable population (1:10).

Population control is possible with the means at hand; the barriers that must be overcome are superstition, religious objectives, political difficulties and just plain ignorance. Our planet is barely able to support its present population, adding four or even only two more billion people by the year 2010 staggers the imagination. Some type of effective control must be instituted world-wide or the consequences will be disasterous in the not too distant future for all of mankind.

The same expanding population that opens up new markets, enhances profits and provides greater consumer affluence also is responsible for the erosion of personal freedom as well as the steady and systematic degradation of our environment.

The most encouraging development concerning population growth to date is the growing recognition of the problem. That is a necessary first step in the right direction, but there is yet a long road to travel before realization of a viable solution to the growth problems of world population.

As the situation stands now, the inevitable decline in the rate of growth on this planet will have to come about from an involuntary and tremendous upsurge in death rates or from a drastic but voluntary fall in our birth rates. The choice is still ours—but will not be for very much longer.

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# CHAPTER II — AIR

## METEOROLOGY AND TOPOLOGY

By Robert T. Williams, Capt, USAF

### *Meteorology*

Meteorology is the study of the atmosphere and its associated phenomena, notably weather. In particular, meteorology concerns itself with studying the effects of changes in some of the basic atmospheric parameters such as temperature, pressure, water content, wind direction and velocity (3:27). Presently, much thought is also being given to the possible effects of changes in the elemental make-up of the atmosphere.

Some of the most recent theories on atmospherics contend that our original atmosphere was composed of methane and ammonia. How, then, have we reached today's life sustaining mixture of oxygen and nitrogen? The answer here, as with nearly anything concerning life, begins with the sun. As Isaac Asimov, noted scientist and author, argues sunlight striking water vapor molecules in the upper portions of the methane/ammonia atmosphere would break the water into its atomic components, hydrogen and oxygen. The hydrogen, being light, would escape the atmosphere for the most part, while the oxygen, being very reactive, would combine readily. In a reaction with methane ($CH_4$), oxygen would form carbon dioxide and more water. With ammonia ($NH_3$), free nitrogen ($N_2$) and water would be formed. Over eons of time, as this process progresses, carbon dioxide becomes the dominant atmospheric constituent. Since oxygen, liberated from the ultraviolet portion of sunlight, cannot combine any further with either carbon dioxide or nitrogen, it forms an ozone layer in the upper atmosphere. Ozone absorbs ultraviolet light and effectively blocks the further photo-dissociation of oxygen and hydrogen. At this point a stable atmosphere has been attained. But what of the oxygen which we breathe? Where did it come from if the carbon dioxide/nitrogen atmosphere was stable (2:224-225)?

The answer, again from the sun, involves what is called the greenhouse effect. Carbon dioxide is transparent to sunlight, but absorbs infrared or heat radiation very well (1:182; 2:157). Thus, sunlight striking the earth warmed the surface but as the surface, in turn, tried to radiate the heat into space, it was trapped in the carbon dioxide atmosphere and resulted in a general warming trend. As the earth warmed, life began which developed the ability to break down water into hydrogen and oxygen through the use of *visible* light, not the ultraviolet portion of the spectrum. The hydrogen and carbon dioxide were combined to support cellular life processes and the oxygen was released to the atmosphere. Thus, the atmospheric oxygen which makes life possible for man was made possible only because life did develop on the earth (2:224-225).

The earth's atmosphere - presently approximately 21% oxygen, 78% nitrogen, and 1% other gases - is also defined in terms of the parameters of pressure and temperature. Early work by men such as Boyle and Pascal set the stage for postulating a working picture of the atmosphere (Figure 1) which, except for a few surprises, was confirmed and elaborated in increasing detail as man took to the air and reached into space (2:161-176).

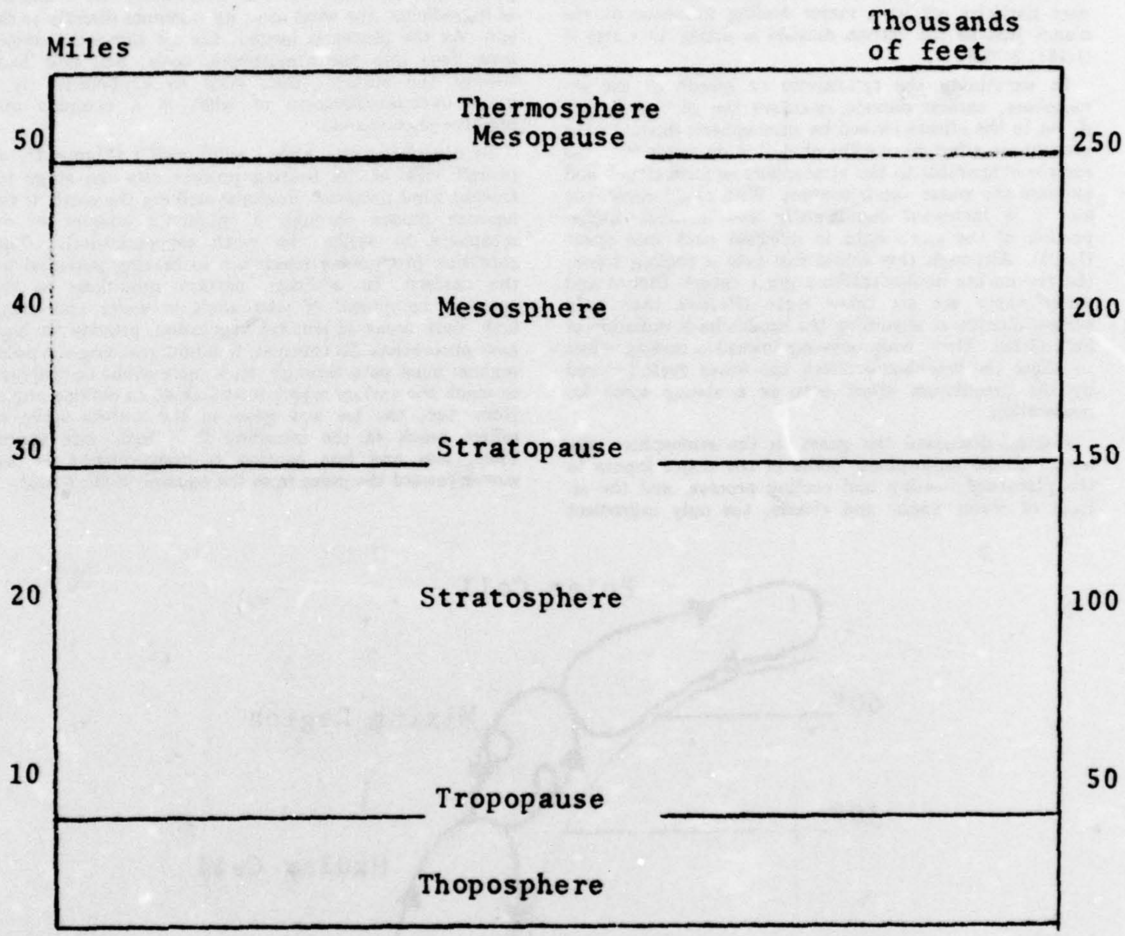


**Figure 1**
**Levels of the Atmosphere (2:175; 3:28)**

**Originally defined as the level which contains all of the earth's weather, the troposphere today is defined from the surface of the earth up to a point where the normal environmental lapse rate no longer holds. This point, called the tropopause, is where the temperature lapse rate, which has caused a temperature drop of about 3.5 degrees F for every 1000 feet of altitude ascended from the surface, suddenly drops off. For the next 13 miles of ascent, the temperature of the atmosphere remains nearly constant. At the end of this rise until the stratopause is reached is about 30 miles. This region of temperature rise is occasioned by the reactions between Ozone which is concentrated in the stratosphere and ultraviolet light from the sun (3:28-29). Indeed, the original definition of the troposphere as the level containing the earth's weather is fairly accurate for the only weather forms which penetrate into the stratosphere are particularly violent forms such as large thunderstorms which form very rapidly and have enormous power.**

**As mentioned earlier, carbon dioxide seems to have been a primary agent in the general warming of planet earth. The development of life which could convert carbon dioxide to cellular products through photosynthesis was advanced as a factor which moderated the warming effect. This cycle was based on an atmosphere and life process. The earth too, plays a big part in the carbon dioxide cycle and balance. In periods of high volcanic activity, tons of carbon dioxide are spewed into the atmosphere. However, as a balancing factor in this portion of the cycle, earthquake activity exposes large areas of new rock which absorbs carbon dioxide in the weathering process (2:157). From this discussion, the interworkings of the atmosphere might seem fairly uncomplicated and straight forward. Unfortunately, such is not the case. In addition to the large amounts of carbon dioxide produced by volcanoes, tons and tons of particles are blown into the sky. After periods of intense activity, historians have documented the dimming of the light of the sun for periods up to several years. Huge regional forest fires and dust storms have also added to dust in the atmosphere from time to time (1:181-182). Accumulations of dust in the atmosphere serve to block**

sunlight from the earth both by absorption and by reflecting of the light back into space. Thus, airborne dust particles act as a major cooling influence on the planet just as the carbon dioxide is acting to warm it (1:181; 2:160).

In examining the reflectivity or albedo of the atmosphere, carbon dioxide re-enters the picture in addition to the effects caused by atmospheric dust. As the greenhouse effect warms the planet, more water from the surface evaporates to the atmosphere to form clouds and increase the water vapor content. With cloud cover, the albedo is increased significantly and a much higher portion of the sun's light is reflected back into space (1:181). Although this would instigate a cooling trend, the results are moderated to a great extent. Clouds and water vapor are six times more effective than even carbon dioxide at absorbing the earth's back radiation of heat (3:30). Thus, while moving toward a cooling effect to offset the greenhouse effect, the water cycle induced by the greenhouse effect acts as a strong force for moderation.

Having discussed the gases in the atmosphere, the layers of the atmosphere, some of the major inputs to the planetary heating and cooling process, and the effects of water vapor and clouds, the only ingredient missing which is needed to make a discussion of weather possible, is the wind. As with everything else in the list of ingredients, the wind owes its existence directly to the sun. As the planet is heated, the air above the heated area rises into the atmosphere, cools, and falls back toward the surface. But, such as explanation is a gross oversimplification of what is a complex and massive phenomenon.

In describing the global wind model (Figure 2), an overall view of the heating process sets the stage for tracing wind patterns. Sunlight striking the earth at the equator passes through a minimum amount of atmosphere to strike the earth perpendicularly. This condition produces a maximum in heating potential for the surface. In addition, surface conditions at the equator, comprised of vast areas of water and many lush, dark areas of tropical vegetation, provide for high heat absorbtion. In contrast, sunlight reaching the polar regions must pass through much more of the atmosphere to reach the surface which it strikes at an oblique angle. Here, too, the ice and snow of the surface serve to reflect much of the incoming light back into space. Thus, less and less heating is accomplished as one moves toward the poles from the equator (3:30; 5:532).

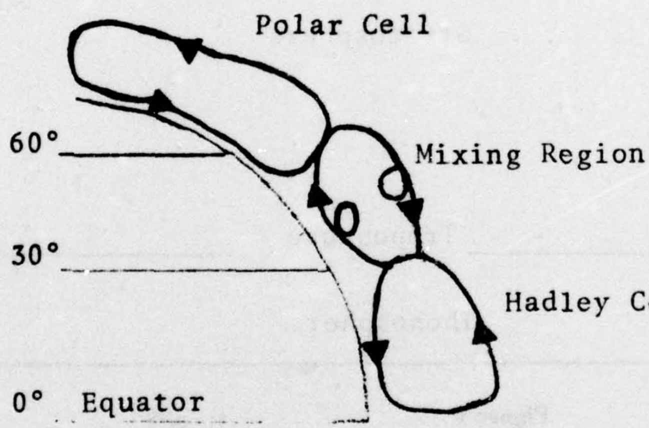


**Figure 2**
**Global Wind Model (3:31; 5:532)**

At this point, the earth possesses all the ingredients for making winds. Air, heated in the tropics, rises and is replaced by cooler air from more polar regions. The heated air then moves poleward to complete the cycle. Again, however, as with most of nature's processes, things aren't quite so simple. The moving air cycle does not extend from the equator to the poles. Air, rising from the equator, cools in the upper layers of the troposphere and begins to fall back to the surface about a third of the way to the poles. Two of these cycles, called Hadley Cells, circle the earth — one north and one south of the equator (5:532). Two polar cells, forming caps over the poles, complete the earth's wind mantle, but here wind flow patterns are more influenced by the surface terrain than by heating patterns (6:383). In the polar cells, vast convolutions of high and low pressure form and move around the earth in a series of interacting currents and eddies (5:532; 6:383). A great deal of mixing and interaction in wind flows occurs along the interfaces between the equatorial Hadley Cells and the polar cells.

Even at this point, the description of the earth's winds is far from complete. A French physicist named Coriolis discovered a force which bears his name and which has a profound impact on the planetary wind patterns. The Coriolis effect is a force which acts at right angles to the winds to change their direction; to

the right in the northern hemisphere and to the left in the southern hemisphere. The effect is much like trying to draw a straight line from the center to edge of a rotating disk such as a record. The resultant path is curved, not a straight line (3:30; 5:532). It is because of the Coriolis force that winds with primary flows of north and south have been deflected enough to pick up the familiar names of trade winds, prevailing westerlies, and polar easterlies (3:31). With the inclusion of the Coriolis effects, a much more accurate picture of the earth's winds begins to develop, but even here the result is only a general model to work with. By mixing the wind with the other ingredients discussed earlier, some of the most awesome and varied phenomena in man's experience came boiling from the cauldron.

*Weather*

Weather might be termed as the portion of meterology one steps out the door into every morning. Produced as a blend of temperature, pressure, water vapor and wind, weather can take on a nearly infinite variety of forms. To speak of weather is to speak of energy. The sun evaporates over 1,000 billion tons of sea water every day. The energy involved in such an operation is over 100,000 times the electric generating capacity of the United States in 1970. Add winds to transport this water vapor (which forms an average of about 50 thousand thunderstorms each day) and the equivalent energy release is on the order of billions of tons of T.N.T. every day of the year (5:528). Weather at its worst, in the form of hurricanes, typhoons, tornadoes, and floods, is responsible for tremendous amounts of damage and suffering every year. Conversely, the good side of weather is reflected in the output from some of the vast food producing areas of the world. Clearly, as weather continues to be man's best friend and worst enemy, an effective system of forecasting or weather modification would appear to have a great impact for the future.

In view of the previous discussion on the components of the weather, it would seem that weather forecasting would rank somewhere between alchemy and astrology as a useful science. Indeed, to anyone caught in a storm on a day with a forecast for clear skies, the weatherman becomes the village idiot for not looking out the window. Surprisingly, though, weather forecasting has come a long way and, as man has stepped into space, so too has his knowledge of weather increased. There are over 23,000 professional and volunteer weather observers in the United States. Around 25,000 surface observations are made around the world each day. There are 10,000 land stations in 130 countries in addition to 6,700 ships having weather measuring equipment. Over 1,200 measurements are made from balloons each day. In addition, satellite observation covers the earth. And yet, despite the vast amount of information gathered each day, Dr. Walter Orr Roberts, head of a global weather research effort, says that only about 20 percent of the earth has an adequate weather observation coverage (5:528-529).

In an effort to develop weather forecasting to the point where it can be called an exact science, the Global Atmospheric Research Program (GARP) has taken the development of an adequate global information network as one of its three aims. The other two include the acquisition of electronic computers having a hundred times the capacity of those presently available and the development of a mathematical model on such a scale as to provide useful forecasting ability (5:528). Far off as such plans might seem, today's forecasts for well covered areas such as the United States are actually quite accurate. Two-day forecasts are now more accurate than one-day forecasts were in the 1960's. On the average, tonight's temperature can be predicted to within 3-1/2 degrees and tomorrow's within 4-1/2 degrees. Using 50 percent as a cutoff for predicting rain or no rain, 87 percent of today's forecasts are good as are 80 percent of tomorrow's. Even at that, weather forecasts are made for wide areas, not for pinpoint locations. Thus, a 10 percent chance of rain forecast for an area may turn out to 100 percent at specific points within the area. Then too, in playing with probabilities, 10 days with 10 percent chance of rain forecasts, almost guarantees rain on one of the days (5:522).

Research has shown that, in the northern temperate zone with its great air mass movements and frontal weather patterns, looking to see what weather may be coming will actually involve watching where the weather goes when it leaves. The great polar convolutions of high and low pressure actually circle the earth every ten to twelve days. Thus, long range forecasting in the mid-latitudes will involve monitoring air masses all across the northern portions of the earth (5:529).

So much for the effects the weather has on man. But what of the effects man has on the weather? What advances have been made in using technology to modify weather? To date, man's attempts at influencing the weather have been aimed primarily at lessening or averting the impact of some of the more violent weather forms. Typically, modification operations involve various types of seeding operations in attempts to induce precipitation from clouds. By adding tiny silver iodide crystals to act as condensation nuclei, clouds can be made to rain. In this way, droughts may be alleviated by inducing clouds to rain over the arid land rather than continue out of the area. So too, hurricanes have been weakened considerably by seeding the cloud wall immediately surrounding the eye. The greatly increased freezing resulting from the crystals causes tremendous amounts of heat to be liberated from the storm. As the eyewall clouds give up the heat energy stored in them, they become much weaker and disrupted. This forces the storm to rebuild the eyewall at a farther distance from the center and at a much reduced wind speed (5:543). In another application, farmers in Russia's Caucasus wheat region have set up batteries of rockets and anti-aircraft guns containing silver iodide crystals. When radar indicates the approach of destructive hail storms, the crystals are fired into the clouds to induce early precipitation in the form of sleet (5:551, 554). Seeding is also used to clear selected areas of supercooled arctic ice-fog to enable aircraft to land and take off in parts of Alaska.

Although man has succeeded, to some extent, in controlling some types of weather, there is one form which seems to defy him at every turn - the tornado. Too small and too short in duration to be effectively detected from space, tornadoes seem to form almost at random, strike with incredible violence, and disassemble to nothingness faster than man can react. The National Severe Storms Forecast Center conducts continuous atmospheric surveillance to spot the conditions under which tornadoes are likely to form and, should such conditions exist in an area, issues a tornado watch via

radio and television to the affected area. When a funnel is sighted or detected on radar, a tornado warning is issued through every means available to warn people to take shelter. Whirling at speeds from 50 to 200 miles per hours and containing suction spots which may be rotating at speeds up to 300 miles per hour, tornadoes move across the earth at about 30 miles per hour. The potential for destruction is beyond man's comprehension. Working with man-made, laboratory tornadoes, Dr. T. Theodore Fujita of the University of Chicago has found that the application of heat kills a tornado. Although not a practical solution to the problem at present, it may perhaps lead to a solution sometime in the future (5:545-547).

So far, the discussion has centered on man's attempts to interact with the weather. Bigger problems may exist, not in man's attempts at change, but in his unintentional interactions with the weather. Industrial man, in burning large quantities of carbon based fuels, is estimated to be adding nearly 9 trillion tons of carbon dioxide to the air each year (3:227). As an addition to the greenhouse effect, this carbon dioxide should begin to produce a warming trend. However, along with the carbon dioxide, man has been dumping countless other tons of gases and particles into the air to form haze layers and condensation nuclei which should contribute to a cooling trend. At present, the two effects appear to be in balance with regard to any effect on the earth's temperature with perhaps a little more evidence pointing to the cooling trend theories (1:181-184; 2:159-160; 3:228).

In the same vein, other scientists are beginning to examine some other possible effects resulting from man's continued use of the atmosphere as a dump. Effects in the ionized layers of the atmosphere and reactions in the chemically reactive ozone layers are being studied. Synergistic effects have yet to be guessed at.

At a more local level, man's pollutants have a significant meteorological impact in urban areas. Reduced sunlight and ultraviolet radiation, increased incidences of fog and rain, and more clouds are a general indication of man's effect on local urban weather. In certain cities ringed by hills - notably Los Angeles - and in others experiencing a stagnant mass of surrounding air, industrial air pollutants coupled with a temperature inversion in the atmosphere have produced air so toxic to man as to have caused upwards of 4,000 deaths in one London case (3:236). Recall that the normal environmental lapse rate is the rate of temperature drop experienced in ascending through the atmosphere. In an inversion, cool air is trapped under a layer of warmer air. As pollutants are released, they rise through the cool air but are trapped beneath the warm layer where, if no winds arise to disperse the accumulation, buildup can cause severe respiratory distress and even death to people in the underlying city (3:31-34).

In this brief look at the subject of meteorology, it should be clear that, indeed, meteorology does present the most complicated series of problems we can imagine. Turning now to topology, even more interrelationships between the earth and its weather will become evident.

### *Topology*

The study of the earth and its associated surface phenomena could properly begin with a study of cosmology and the origins of the solar system. Numerous theories abound on such origins and are beyond the scope of this chapter. Instead, an arbitrary start of about 200 million years ago provides a basis for describing the forces which have shaped today's earth. At about the time of 200 million years ago, all the land on the earth was a part of a single, giant land mass called Pangaea. At about 135 million years ago Pangaea had begun to break up in continent size pieces to slowly "float" about the planet's surface like large icebergs (4:6-7). Such movement is possible because the earth's core is molten rock. Toward the surface the moltenness becomes more and more sluggish until, where the continental surface plates begin to move, it is a semiplastic flow mechanism (2:114-125; 4:7).

After millions of years of drifting around the planet, the plates on which the continents were drifting began to interact with each other. As two plates would drift apart, material from the earth's mantle would rise up between them to fill in the void. Such a process is occurring in both the Atlantic and Pacific oceans. The most recent evidence in each area is the formation of the island of Surtsey from an undersea volcano near Iceland and the recent eruptions of Hawaii's Kilauea and Mauna Loa (4:3, 26). On other fronts, as continental plates drifted together, one would ride up on the other and force it back down toward the mantle. It is in these areas that the world's large mountain ranges were formed. Such is the case with the Himalayas where the Indo-Australian plate has crashed into the Eurasian plate. The same holds for the Rockies, the Andes, and the Alps (4:10-11,32).

The mountainous profiles of the earth have had a profound influence on man. By directing the course of runoff waters, affecting the weather, and providing surface barriers, mountains and hills have shaped man's evolution and spread on the planet. In newly formed areas, water run off is swift and violent, soil is shallow to nonexistent, and surface contours very irregular. In contrast, in older land areas water runoff forms broad, slow moving rivers, weathering has produced arable top soil, and the surface is gentle enough to permit easy travel.

From an environmental standpoint, however, the topology of the earth is significant in two areas; weather effects and pollution problems.

Locally, because of urban development, man is primarily faced with the problems of pollution. The difficulties involved with obtaining and protecting a water supply are counterbalanced by problems involved in determining the assimilative capacity of the supply in transporting and disposing of wastes. With air, the supply has not become a problem but its use as an atmospheric dump bring up the same problems faced with water. Especially as man becomes more knowledgeable of his environment and more restrictive of himself in its use, topologically influenced assimilative capacities will come under closer scrutiny.

Regionally, topology affects many of man's undertakings. Mountain ranges like the Rockies force water laden maritime winds aloft and produce prodigious amounts of rainfall along their front faces while points inland receive little or no rain. Inland lakes and seas provide the water vapor that moderates the weather of the lands in their lee. Thus have many of the worlds great agricultural regions been blessed by some topological feature which provided the necessary conditions for growing.

Globally, topology may contribute more to man's condition than would be apparent at first glance.

National Oceanic and Atmospheric Administration (NOAA) scientists have experimented with computer simulations of the earth's weather. The first model they examined was that of a smooth earth with no protruding features. A second model included the topological features of the earth. It was found that the topological model more closely duplicated actual wind and pressure patterns than did the smooth model. In fact, it was found that, for the northern hemisphere, major mountain ranges had a major effect on the weather and climate. While thermal heating and cooling effects held for phenomena in the lower portions of the troposphere, the mountains' influences were exhibited in the upper troposphere and stratosphere. Thus, stationary low pressure cells are formed to the lee of all major ranges. Again, interactions with all the other inputs to the global weather machine serve to produce the general weather patterns of the earth (6:382-383).

As the other major input to the global topology, the oceans have at least as great an impact as the land. Sources of moisture, they also contain vast currents which warm or cool various palces on the globe to effectively change their climates. England's moderate climate is dependent to a large extent on the warm Gulf Stream which originates in the tropical waters of the Caribbean.

*Conclusion*

Taken together, meteorology and topology represent a highly complex and far reaching series of relationships. What affects one is almost certain to have some impact on the other. With man entering the picture with increasing technology, both his projects and his byproducts will continue to impact both meterology and topology. Hopefully, the impact will be beneficial, for to disrupt a system as huge and as intricate as this one could possibly have disastrous results.

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# CHAPTER II — AIR

## PARTICULATES, GASES, AND PHOTO OXIDANTS

By Lee Schmidt, Capt. USAF

### *Introduction*

Particulates, gases, and photo oxidants constitute nearly all of the additives to normal air. The quantities of major pollutants input to air by the major sources are depicted in Table 1 (5:4-6).

What are the criteria for classifying an atmospheric additive as a pollutant? McCormac (4:11) lists four: (1) toxic to human beings, (2) irritation to skin, eyes, or respiratory tract, (3) economic damage to vegetation and inanimate material, and (4) reduction of visibility and aestetic amenities. However, the true effects of pollutants depend upon their concentration, the length of exposure, and their possible accumulative effects.

The life cycle of atmospheric pollutants consists of generation by combustion or mechanical processes, movement (or lack thereof), aggregation, and, finally, removal by wind, rain, or volume dilution. The rate of change of the quantity (x) of a pollutant over time (t) is equal to the rate of generation ($\alpha$) minus the rate of removal (b) which may also depend on the concentration. Mathematically this is expressed as, $dx/dt = \alpha \cdot bx$ or $x = (\alpha/b)\ e^{-bt} + c$, where c is the initial concentration (4:12). When the pollutant generation rate so exceeds the removal rate that the difference overloads the assimilative capacity of the air in the region, then an air pollution problem exists.

### *Particulates*

Particulates are small particles of a material suspensed in a medium thus forming a colloid. If the medium is air, the colloidial suspension is called aerosol. Particulates range in size from $0.0002\mu$ to $500\mu$, where $\mu$ is a micron, $10^{-6}$ meter (5:66). Characteristics — definitions and properties — of particulates will now be described, followed by a discussion of the sources and effects of particulate pollution.

Four general types of particulates require definition for distinction: dusts, fumes, mists and smokes. Dusts are dispersion aerosols of solid particles formed by a disintegration process such as grinding or erosion. Fumes are solid particles generated by the condensation of vapors by sublimation, distillation, calcination or chemical reaction. Mist are liquid particles which arise from vapor condensation, chemical reactions, or by atomization of a liquid (2:100). Smokes are condensation aerosols which may be solids and/or liquids.

Smoke is formed when the combination of fuel used and method of burning is such that incomplete combustion results. A fuel produces smoke when it has been heated to a sufficiently high temperature.

TABLE 1
Sources of Major Pollutants *

Weight (million tons/year (1968)

| Source | CO | $NO_x$ | HC | $SO_x$ | Part. | Source Totals | Source Percentage |
|---|---|---|---|---|---|---|---|
| Transportation | 63.8 | 8.1 | 16.6 | 0.8 | 1.2 | 90.5 | 42.25 |
| Fuel Combustion | 1.9 | 10.0 | 0.7 | 24.4 | 8.9 | 45.9 | 21.43 |
| Ind. Processes | 9.7 | 0.2 | 4.6 | 7.3 | 7.5 | 29.3 | 13.68 |
| Solid Waste Disposal | 7.8 | 0.6 | 1.6 | 0.1 | 1.1 | 11.2 | 5.23 |
| Misc. | 16.9 | 1.7 | 8.5 | 0.6 | 9.6 | 37.3 | 17.41 |
| Component Totals | 100.1 | 20.6 | 32.0 | 33.2 | 28.3 | 214.2 | |
| Component Percentage | 46.73 | 9.62 | 14.94 | 15.50 | 13.21 | | |
| Weighted Percentage | 1.51 | .64 | 13.49 | 38.89 | 45.47 | | |
| Toxicity Weighting Factor | 1.0 | 2.07 | 28.0 | 77.8 | 106.7 | | |

* Babcock, L. R., Jr. "A combined pollution index for measurement of total air pollution," *Journal of the Air Pollution Control Association,* 20:658 (1970). Department of Health, Education, and Welfare. *Nationwide Inventory of Air Pollution Emissions.* (Washington: Government Printing Office) 1968

The properties of particulates need to be considered in three areas— surface effects, optical influences, and suspension life (2:68). The three important surface effects are: nucleation, adhesion or coagulation, and absorption. Nucleation is the property of serving as a site for moisture condensation. Adhesion is the situation which occurs as particles in their random movements collide and hold together to each other thus aggregating or forming larger particles. The smaller the particle size the greater the tendency to adhere (3:354). Sorption is the "phenomenon by which molecules are taken up by a particle (3:354)"; the molecules impact, but do not

rebound. If the molecule is physically attracted and held, it is absorption. If the molecule is held by a chemical reaction, it is chemisorption. If the molecule dissolves into the particle, it is absorption (5:68).

Optical influences of particulates are due to their light absorption and scattering effects which cause reduced solar radiation and illumination and diminished perception. Particles smaller than 0.1$\mu$ refract the light; while particles greater than 1$\mu$ intercept or scatter the light (5:68). Suspension life (settling rate) is dependent on particle size, density, and turbulence (5:68). The settling velocity (V, centimeters per second) of particles greater than one micron is expressed in Stokes law as:

$$V = \frac{gd^2 \ (\rho 1 - \rho 2)}{18n}$$

where g = acceleration of gravity (cm/sec$^2$ ), d = particle diameter (cm.), $\rho 1$ and $\rho 2$ the density (grams per centimeter cubed) of the particles and of air respectively, and n = the viscosity of air (in poise) (3:353).

The quantity of aerosols generated world-wide by various sources is indicated in kilograms per year in Table 2 (4:27). This table shows that over 88 percent of the aerosols arise from natural sources. Particles greater than 10$\mu$ result from mechanical processes such as pulverizing, grinding, spraying, or wind erosion. Particles between 1 and 10$\mu$ result from local soil, process dusts, or sea spray. Particles smaller than 1$\mu$ are the products of combustion or are photo-chemical aerosols (5:69).

TABLE 2

World-Wide Emissions Aerosols*

| Source | x10$^{11}$ kg/yr |
|---|---|
| Sea Salt | 9 |
| Natural $H_2S$ | 1.8 |
| Natural N Compounds | 6.3 |
| Natural Terpenes | 1.8 |
| Man-made Particles | .83 |
| Man-made $SO_2$ | 1.3 |
| Man-made N Compounds | .27 |
| Man-made Hydrocarbons | .25 |
| Wind Dust | 1.8 |
| Forest Fires | .027 |
| Volcanoes | .036 |
| Meteoric Dust | .05 |
| | 23.463 |

* (4:27)

Air pollution effects human beings, vegetation, animals, man's property and materials, and the environment. The effects of particulates on vegetation and animals are relatively minimal. Encrusted settled dust on plants interferes with photosynthesis and $CO_2$ exchange (5:71-72). Some toxic components —arsenic, fluorite, and lead contained in dusts are harmful to plants and animals (1:244). The type and extent of particulate damage to materials are a function of the chemical composition and physical state of the particulates (5:77). The damage may be passive—as in the settling of dusts and soiling by dusts and smokes—just requiring more frequent cleaning of man's property. It may be more corrosive, especially if the particulates are tarry, sticky, and acidic. Fumes and mists react with paint to produce discoloration and softened finishes (1:249).

Particulates affect the human body primarily internally; particulates enter the body almost exclusively by the respiratory tract. Particle size is important, as the smaller particles get further into the body (5:72-73). Three patterns of effects result from the inhalation of dusts and fumes. In a benign pattern, the particles are usually inert and mostly just interfere without causing any recognizable pathological effect. Effects upon the lung tissue and lung-function result from the accumulative disposition of dusts. Some of these results are silicosis, asbestosis, and talcosis. A pattern of systematic effects (on other organs) results from the absorption of the dust and fumes from the lungs from disposition. The deposited particles may cause their problems because they have sorped irritating gases or because they are intrinsically toxic (1:207-208).

Particulates affect the environment by causing changes in solar radiation and climate. Particulates exert an influence—the result of light scattering and absorption—on the amount and type of solar radiation reaching the earth's surface. Illumination may be reduced one-third. The intensities of light from both the object and the background, and the distinguishing difference between them, are all diminished. Reduced solar radiation may also upset the earth's heat balance. Climate is affected by the quantity of particulates because they influence the formation of clouds, rain, and snow by acting as nuclei for moisture condensation (5:80-81).

*Gases*

Although over 88% of the pollutional load is input into the air media by natural sources (4:27), and air pollution problem only exists where the quantities input exceed the assimilative capacity of the local air media to disperse, dilute, or absorb. In those limited areas, man-produced pollutants are almost always the culprit. The prime gases of concern are the vaporous forms of the compounds of carbon, sulphur, halogens, and nitrogen.

The gaseous compounds of carbon of concern are carbon monoxide and the hydrocarbons. Carbon monoxide (CO) is a colorless, odorless, tasteless, gas above minus 192°C, 96.7% as heavy as air, and not appreciably soluble in water (2:188; 5:8). It is formed either by (1) incomplete combustion, $2C + O_2 - 2CO$, or high temperature (greater than 1745°C) reactions, $CO_2 + C - 2CO$, $CO_2 = CO + 0$ (3:308). Man-generated sources of CO are primarily transportation (68%) and industrial processes (11%). The annual mean concentration of carbon monoxide in the air of U. S. cities is 5 - 15 parts per million (ppm) (1:227; 4:39). Approximately 200 tons of CO are released annually world-wide (1:226), but the capacity of the natural soil sink is over five times the annual discharge. This natural soil sink capacity is dependent on particular soil microorganisms, anaerobic methane-producing bacteria, *Methanosarcina barkerii* and *Methanobacterium* for *formicum* (4:310). The effects of carbon monoxide on plants are nil and are minimal on humans at low levels (less than 100 ppm). However, at higher levels, CO has a toxic effect due to the preemptory reaction of CO and hemoglobin, which reduces oxygen transport to

inadequate levels (4:39).

Organic vapors, hydrocarbon compound gases, have little direct toxicity; but are of concern as air pollutants because they are a necessary but not sufficient ingredient of photochemical reactions forming smog (4:40-41). Hydrogen and carbon form tens of thousands of compounds. Those compounds with 1-4 carbon molecules are gases, while those with more than 5 carbon molecules are solids or liquids, with those with less than 12 carbon molecules being volatile (5:37-38). The simplest of the hydrocarbon gases is methane, $CH_4$, which occurs naturally from the decomposition of organic matter (5:40-41). This decomposition is performed by anaerobic bacteria, $2CH_2O \cdot CO_2 + CH_4$ (3:332). Methane normally has a high natural level, but fortunately does not participate in photochemical reactions. Other carbon compounds are either acyclic—carbon chains, or alicyclic—carbon rings (3:333). The natural sources of carbon compound gases are methane and terpenes. Terpenes are naturally effused by members of the plant families *coniferae* and *myrtaceace* and the genus *Citrus* (3:331). Sixty percent of the man-generated hydrocarbons are from transportation (1:224). For example, a typical automobile without emission controls produces hydrocarbons equivalent to 3.3% of its gasoline input (1:264). Thus, for U.S. cities, the annual geometric mean of hydrocarbon concentration is 2 to 3 ppm (1:231). Hydrocarbons cause no significant effects until after photochemical reactions occur.

Sulfur compounds are hazardous because they are both irritating and acidic. Eighty percent of the sulfur vapors emitted into the air are from man's activities (see Table 3) and 73% of these are from combustion in stationary power plants (also see Table 4). Sulfur dioxide ($SO_2$) and sulfur trioxide ($SO_3$) form in the combustion process in the ratio of 25-30 to 1 (1:226-27).

TABLE 3

World-Wide Emissions of Sulfur*

| Source | x10 10 kg/yr |
|---|---|
| $SO_2$ — Coal Combustion | 4.7 |
| $SO_2$ — Petroleum Combustion | 1.3 |
| $SO_2$ — Smelting | .7 |
| $H_2S$ — Bacteria | 8.8 |
| $SO_4$ — Sea Spray | 4.0 |
| | 19.5 |

* (4:26)

TABLE 4

Generalized Emission Factors for Sulfur Dioxide from Selected Sources*

| Source | Emission Factor |
|---|---|
| Combustion of Coal | (38 times % S by weight) lb $SO_2$/ton of coal |
| Combustion of Fuel Oil | (158.8 times % by weight) lb $SO_2$/1000 gal. of oil |
| Municipal Incinerators | 1.2-2.0 lb $SO_2$/ton of refuse |
| Sulfuric Acid Manufacture | 20-70 lb $SO_2$/ton of 100% acid produced |
| Copper Smelting | 1400 lb $SO_2$/ton of concentrated ore |
| Lead Smelting | 600 lb $SO_2$/ton of concentrated ore |
| Zinc | 1090 lb $SO_2$/ton of concentrated ore |
| Kraft Paper Mill Recovery Furnace | 2.4-13.4 lb $SO_2$/ton of air-dried pulp |
| Sulfite Paper Mill Recovery Furnace | 40 lb $SO_2$/ton of air-dried pulp |

* National Air Pollution Control Administration, *Control Techniques for Sulfur Oxide Air Pollutants*, NAPCA Publication No. AP-52 (Washington: Government Printing Office, 1969).

In the atmosphere, sulfur dioxide is slowly converted to sulfur trioxide with moisture content and sunlight influencing the oxidation. With moisture present, sulfur trioxide immediately forms sulfuric acid, which contributes to haze (1:226).

The applicable chemical reactions are $S + O_2 = SO_2$, $SO_2 + O_2 = 2SO_3$, $SO_3 + H_2O - H_2SO_4$ (5:52—53). Mean annual concentrations of sulfur oxides in U.S. cities range from 0.01 ppm to 0.18 ppm, and up to 0.5 ppm in highly industrialized areas (1:226). Sulfur oxides produce effects on plants, humans, and cause severe damage to man's property and materials. Sulfur dioxide is a direct fumigant to plants, entering the leaf stomata as a gas. If the leaf cells cannot detoxify the sulfate, the chlorophyll will be destroyed and photosynthesis cannot be sustained (1:246). The threshold level for plant injury is 0.25 ppm $SO_2$ for 8 hours (4:114). Acute exposure to high levels causes leaf necrosis, while chronic exposure causes chlorosis or bleaching of green portions. Plant injury is increased if the stomata is open and if humidity is high. Plants also suffer burns from sulfuric acid droplets (3:314; 4:132). The impact of sulfur oxides on the human body is primarily to the respiratory tract and lungs; morbidity and mortality from diseases of these areas increasing as exposures to increasing sulfur oxide concentrations. Sulfur dioxide adversely affects metals, building materials, paint, leather, paper, textiles, and dyes. The effects—discoloration, leaching embrittlement, reduced strength, and fading—are influenced by moisture, temperature, sunlight, and air movement.

Hydrogen sulfide is an extremely toxic, evil-smelling gas which is readily burned to $SO_2$ (2:175). Its natural sources, about 268 million tons annually, are from the decay of organic matter and the biological reduction of sulfate (3:311). Major industrial sources are viscose rayon spinning, coke ovens, and petroleum refinering (2:175). Hydrogen fluoride (HFl) is extremely corrosive, poisonous liquid with a low boiling point (19.4°C) (2:177). Its maximum allowable concentration is 3 ppm, but it is seldom above 0.018 ppm (2:14). Sources are

primarily electrolytic aluminum processing, the ceramics industry, and the superphosphate industry (2:178). Main adverse effect of HFl is fluorosis in cattle at levels above 50-300 ppm (2:177). Halogenated compounds have maximum allowable concentrations of 3 ppm chloride; 5-10 ppm hydrogen chloride; and 100-200 ppm chlorinated organics (2:180). The sources are primarily chemicals manufacture or handling. Their effects are corrosion, respiratory irritation, and damage to vegetation (2:181).

Seven oxides of nitrogen ($N_2O$, NO, $NO_2$, $NO_3$, $N_2O_3$, $N_2O_4$, $N_2O_5$) and two hydrated oxides ($HNO_2$ and $HNO_3$) can theoretically exist in the atmosphere, but nitrous oxide ($N_2O$), nitric oxide (NO), and nitrogen dioxide ($NO_2$) primary occur (2:182). $N_2O$ is a normal constituent—0.5 ppm—of air; but it is extremely unreactive, and consequently not a pollutant. The nitrogen pollutant cycle is: NO $\xrightarrow{\text{oxidated}}$ $NO_2$ $\xrightarrow{\text{oxidated}}$ $N_2O_5$ $\xrightarrow[\text{vapor}]{\text{water}}$ $HNO_3$ $\xrightarrow[\text{salts}]{\text{metal}}$ nitrate particulate (2:183). The sources of nitrogen emissions are indicated in Table 5; but the oxides of nitrogen derive mainly from combustion of fuel and certain chemical operations (2:183). In combustion, fuel plus air yields NO; the amount of NO in the combustion effluent depends on the flame temperature and the rate of cooling (quenching). NO concentration increases as temperature does; but, its rate of decomposition decreases with decreasing temperature. Two examples of emission rate are 55 lb NO per ton of nitric acid produced and 5 grams of NO per mile from automobiles (2:188). Nitrogen dioxide ($NO_2$) is a red-brown gas, boiling point 21°C, which is extremely irritating to mucous tissues; its odor threshold is 1-3 ppm (4:36). At concentrations greater than 10 ppm, $NO_2$ has an adverse effect: thickening of the blood-gas barrier through replacement of the thin-type cells of the alveolar wall with cuboidal of columnar types (4:113). Bronchiolitis with focal pneumonitis results from $NO_2$ exposures of 50-100 ppm, but recovery in 6-8 weeks is expected. Exposure to over 300 ppm $NO_2$ is generally fatal. Nitrogen dioxide causes about the same plant injury symptoms as sulfur dioxide: white or tan colored lesions between the main veins. In low light intensity, 2.5-3.0 ppm for two hours is the adverse threshold (4:139-140).

TABLE 5

World-Wide Emissions Nitrogen

| Source | $x10^{11}$ kg/yr |
|---|---|
| $NH_3$ -- Bacteria | 8.6 |
| $N_2O$ — Bacteria | 3.4 |
| NO — Bacteria | 2.1 |
| $NO_2$ — Coal Combustion | .074 |
| $NO_2$ — Space Heating | .045 |
| $NO_2$ — Motor Vehicles | .02 |
| $NO_2$ — Other Combustion | .007 |
| $NH_3$ — Combustion | .031 |
| | 14.277 |

*Photooxidants*

Photochemical oxidant smog is characterized mainly by an unusual odor, intense eye irritation, and highly restricted atmospheric visibility even when relative humidity is low. This smog is the result of a reaction between hydrocarbon and nitrogen oxides triggered by bright sunlight. The two pollutants, hydrocarbons and nitrogen oxides, first become concentrated in an atmosphere made stagnant by low wind speeds and an intense atmospheric inversion; the sun-induced reactions follow. The major source of both hydrocarbons and oxides of nitrogen is the exhaust gases from motor vehicles (2:243).

The specific nature of the photochemical reactions depends on a variety of factors: light intensity and its spectral distribution, hydrocarbon reactivity, ratio of hydrocarbons to nitric oxide, meterological variables—air movement, height and intensity of atmospheric inversion—, and the presence of light absorbers other than $NO_2$ (2:248-49). The reactivity of hydrocarbons can be rated by yield of various products, by intensity of various effects, by rate of disappearance, or by rate of oxidation of NO to $NO_2$ when irradiated. Olefins and a few aromatics are most reactive, while acetylene and benzene are nearly inert. Molar ratios of $NO_2$ to hydrocarbon of 1:1 to 1:3 yield the greatest reaction (2:251).

The initial reaction in atmospheric photooxidation processes is the absorption of ultraviolet light energy by $NO_2$, which then decomposes (photolyzes) to nitric oxide and atomic oxygen: $NO_2 + h\nu$ (3.1 eV) $\rightarrow NO_2 \cdot NO + 0$. Then ozone is formed, which decomposes rapidly unless some other energy—absorbing molecule—free radical (R) is present: $0 + 0_2 + R \rightarrow 0_3 + R$ (2:245-46). Free radicals are chemical groupings that are not recognized as stable molecular compounds; nor are they ions, as there is no ionic charge (1:234). They are formed from aldehydes, ketones, organic peroxides, organic nitrates, and hydrogen peroxide (4:338). A fourth reaction, $0_3 + NO \rightarrow NO_2 + 0_2$, is regenerative; however, in the presence of certain hydrocarbons (HC), some atomic oxygen, ozone and nitric oxide react with the hydrocarbons to form a variety of products and intermediates, such as aldehydes, peroxides, hydroperoxides, alkyl nitrates, carbon monoxide, peroxyacetylnitrate (PAN), and peroxybenzoyl ($PB_zN$) (2:246-47). These ractions can be generalized in the following equations: $0_3 + HC \rightarrow$ aldehydes + complex organics; $HC + 0_2 + NO_2 +$ v.v. $\rightarrow 0_3 +$ aldehydes + PAN + oxidation products. The oxidation products form an aerosol haze. The aldehydes, PAN, and complex organics cause eye irritation. PAN and $0_3$ cause plant damage (2:246).

The principal effects of photochemical oxidant smog are "eye irritation, damage to sensititve vegetation, a reduction in atmospheric visibility, deterioration of materials, and possible effects on the respiratory systems of men and animals (2:252)." Formaldyhyde, acrolein, PAN, and $PB_zN$ are primarily responsible for the eye irritation; generally, an oxidant index of 0.1 to 0.15 ppm is sufficient (2:253). The photochemical oxidents, as a group, cause more injury to plants than the fluorides and sulfur dioxides (1:246). The first noticeable effects are silvering and bronzing of leaves; followed by cell collapse and necrosis (2:253). The principal phytotoxicants are ozone, $NO_2$, and PAN. Ozone enters the leaf through the stomata and causes four general types of lesions—pigmentation, chlorosis, bleaching, and necrosis (4:135-36). Ambient air concentrations of 0.03 ppm or more for 4-8 hours per day is

sufficient to cause $O_3$ injury (4:136). Environmental factors predisposing plants to $O_3$ injury are poor nutrition, low light, high relative humidity, and moderately high temperatures (4:137). Ozone and sulfur dioxide combined produce adverse synergistic effects. PAN injury occurs after only 2-3 hours exposure to 0.01-0.05 ppm and appears as glazing or bronzing lower leaf surfaces (1:246; 2:253; 3:340; 4:138). Plants are more sensitive to PAN injury during periods of high light intensity (4:139). PAN suppresses photosynthesis and damages the sulfhydryl group of proteins (3:340; 4:138). Visibility reduction, possibly the most widely noticed effect, is the result of photochemical aerosol. The photochemical aerosol contains compounds of carbon, hydrogen, oxygen, sulfur, nitrogen, and halides; and has a particle size centering at 0.3 microns, the optimum size for scattering light (2:253). The ozone content of smog is the principal factor in the deterioration of materials.

Ozone is a strong oxidizing agent and a very reactive substance. It causes the cracking of rubber under tension at air concentrations of 0.01 to 0.02 ppm. Ozone weakens fabric fibers in the following order of susceptibility: polyesters, nylon, acetate, and cotton. Ozone and nitrogen oxides act on dyes, among which certain blue and green shades were easily faded by nitrogen dioxide (1:249).

The effects on man's respiratory system are still incomplete studies and are controversial, but some impairment of pulmonary function does occur (2:254).

*Summary*

Although materials are constantly being added to the air by natural processes, an air pollution problem does not occur until the concentrations in a local area from man-generated sources exceed the assimilative capacity. Only atmospheric additives which damage human health or valuables are air pollutants. The particulates—dust, fumes, mists, and smokes—have properties—surface effects: nucleation, adhesion, and sorption; optical effects; and suspension life—which influence the extent of their adverse effects on man, vegetation, property, and climate. Most pollutant gases—carbon monoxide, sulphur oxides, oxides of nitrogen, hydrocarbons—result from the combustion of fuels and adversely affect primarily man's respiratory tract and vegetation. Hydrocarbons and nitrogen oxides concentrated in the presence of bright sunlight and free radicals produce photochemical oxidant smog, which is very damaging.

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# CHAPTER II — AIR

## MEASURING AIR POLLUTION AND AIR QUALITY

By Wayne D. McDermott, Capt, USAF

### *INTRODUCTION*

Air pollution is everone's concern. The purpose of this paper is to give the reader an awareness of and a conversational knowledge of air pollution and air quality. This will be done by presenting the discussion under four topic areas. First, the main air pollutants will be identified and discussed briefly. Second, the method of measuring these pollutants in the ambient air will be presented. Third, air quality will be discussed with emphasis given to Ohio's "Air Quality Index." Last, ideas will be presented to the reader of what can be done to help reduce the air pollutants so that clean, safe air can be breathed by all.

> Air pollution can kil - and it has. . . . It may shorten the life of whatever it touches - and it touches virtually everything (10:3).

### THE MAIN AIR POLLUTANTS

Air pollutants are classified as either primary or secondary.

> Primary pollutants are emitted directly to the atmosphere from specific sources (eg. smokestacks, auto exhausts). Secondary pollutants are those produced by the reaction of two or more primary pollutants or material components of the atmosphere through either photochemical (solar radiation) or non photochemical reactions (8:34).

The five main primary pollutants are carbon monoxide, particulates, hydrocarbons, nitrogen oxides, and sulfur oxides. The main secondary pollutant is photochemical oxidates. Table 1 shows the total air pollution per year in the United States.

#### *Carbon Monoxide*

Carbon monoxide is a colorless, orderless, tasteless, and lethal gas that is the product of incomplete combustion of carbonaceous materials (3:19). The amount of carbon monoxide emissions exceeds *all* other pollutants. A large amount of this gas can kill while smaller amounts cause dizziness. This gas is especially dangerous for people who suffer from heart disease, asthma, and anemia (6:4). While the transportation industry is the largest source, carbon monoxide is also a by-product of explosions, firing of weapons, solid waste combustion, and cigarette smoking (8:75).

TABLE 1

Million Tons of U.S. Air Pollution/Year (6:10).

| Source | Hydro-Carbons | Sulfur and Nitrogen Oxides | Carbon Monoxide | Parti-culates | Total |
|---|---|---|---|---|---|
| Motor Vehicles | 20 | 12 | 112 | 1 | 145 |
| Factories and Fuel Use | 6 | 42 | 14 | 22 | 84 |
| Refuse Disposal and Miscellaneous | 11 | 3 | 26 | 14 | 54 |
| Total | 37 | 57 | 152 | 37 | 283 |

#### *Particulates*

Particulated are any solid or liquid matter dispersed in the air which do not exceed 500 microns, approximately 1/50 of an inch (1:17). Suspended particulates are those which remian airborne for a significant period of time (1:18). Particulates which cause the main concern are those which are or carry poisonous or disease-producing substances such as asbestos, arsenic, beryllium, and lead (1:17). Particulates are also responsible for causing haze. Additionally, the synergistic effect caused when particulates are combined with other gaseous pollutants gives reason for concern. For example, inhaling sulfur dioxide, absorbed by a particulate, will cause considerably more damage than if it had been inhaled by itself (1:17). The major sources of particulates are automobiles, coal-burning power plants, open fires, fertilizers and building materials.

#### *Hydrocarbons*

Hydrocarbons are created through incomplete combustion of gasoline, coal, oil, or wood; evaporation of gasoline or industrial solvents; and decomposition of all life forms (3:21). This pollutant is a main ingredient necessary to form photochemical smog (8:102). "Hydrocarbons have produced cancer in animals, (and) may be the cancer-producing element in cigarette smoke (6:5). Additionally, hydrocarbons may inhibit plant growth, contribute to eye irritation, and affect the

pulmonary functions (8:102). The main source of this pollutant is the gasoline powered vehicle.

*Nitrogen Oxides*

The primary pollutant is nitrogen dioxide which can cause irritation to the lungs, nose, and eyes (8:96). It is also a necessary ingredient in photochemical smog, which reduces visibility (1:64). The main sources of nitrogen dioxide are the automobile, fossil fuel-burning, fertilizer, and the explosive industry (1:64; 3:21).

*Sulfur Oxides*

The primary sulfur oxide pollutant is sulfur dioxide which in air with moisture will change into sulfuric acid. Sulfur dioxide, by itself, irritates the respiratory tract and has been related to an increase in death due to cardiovascular disease in older people (1:40). Additionally, this pollutant is harmful to vegetation. Sulfuric acid, as a pollutant, is a major producer of haze and is a strong corrosive agent on such items as steel, nylon hose and stone sculpture (3:22). The main source of sulfur dioxide is the combustion of fossil fuels such as coal and oil.

*Photochemical Oxidants*

Commonly referred to as "Los Angeles type smog," this pollutant is created by the interaction of hydrocarbons and nitrogen oxides in the presence of solar radiation (1:75). The principle by-product of this process is ozone and it is usually the element measured to indicate overall photochemical oxidant concentrations in the ambient air (1:76). The smog reduces visibility and is irritating to the eyes and mucus membranes in the human respiratory system (1:75). "Injury to vegetation is one of the earliest manifestations of photochemical air pollutants . . ." and can vary from destruction, to growth alterations, to reduce yields, to changes in the quality of plant products (8:122-123). The major sources of the primary pollutants which make up photochemical smog were previously identified under hydrocarbons and nitrogen oxides. . . . Recorded concentrations remained the same at one site; nine sites recorded lower values; and eight sites recorded increases (1:41).

## MEASURING THE POLLUTANT

The purpose of measuring is to determine the concentration of the pollutant and this can be done two ways. First, measurement can be made at the source to determine how much pollutant that source is emitting into the atmosphere. Second, measurement can be made by sampling the ambient air; this will determine the pollutant concentration at the sampling point. Air quality is based on the second method. The purpose of this section is to identify the types of equipment that are used to gather the pollution concentration data. As in the previous section, measurement methods presented will be restricted to the six main pollutants. Table 2 lists additional equipment not discussed in this section. The interested reader, wanting a more detailed presentation of pollution measurement, is directed to bibliography entry numbers 8 and 9.

*Carbon Monoxide*

The nondispersive infrared analyzer is the most commonly used device to measure carbon monoxide in the atmosphere (8:85). This device operates on the principle that the carbon monoxide infrared absorption spectrum is sufficiently characteristic that it can be measured in the presence of other gases (8:85) The advantages of this device are: (1) it is not sensitive to air flow rate, (2) it is relatively independent of ambient air temperature changes, (3) it has short analysis response times, and (4) it can be operated by non-technical personnel (8:86). The main disadvantage of this device is its cost, ranging from $4,000 to $8,000 per unit (4).

| *POLLUTANT MEASURED* | *MEASURING DEVICE* | *METHOD* | *COST* |
|---|---|---|---|
| Sulfur Dioxide | Electroconductivity Analyzer | Electrical Conductance | $3300 |
| | Billion-Aire Trace Gas Analyzer | Ion current measurement | . . |
| | Titrilog | Coulometric | $4750 |
| Total Hydrocarbons | Infrared Analyzer | Infrared Absorption | $3600 |
| Ozone | Ozone Photometer | Ultraviolet Absorption | . . . . |
| | Ozone Meter | Coulometric Measurement | $1500 |
| Nitrogen Oxides | Nitric Oxide | | |
| | Nitrogen Dioxide Analyzer | Colorimetric | $2700 |
| Carbon Monoxide | Ultragas 3 Analyzer | Electrical Conductance | $2000 |
| Oxidants | Oxidant Analyzer | Colormetric | $2700 |

TABLE 2

Automatic Gas Analyzers for Atmospheric Pollutants (9:7-5—7-7).

*Particulates*

Suspended particulate concentration is usually measured with one of two devices; the high volume sampler or the tape sampler. The high volume sampler, usually referred to as "Hi-Vol" is really nothing more than a vacuum which pulls the air through a special filter at a rate of 40 - 60 cubic feet per minute (4; 9:7-2). The particulates collected on the filter are analyzed in terms of mass determination and chemical analysis to measure how much particulates are in the air. From time to time, the particulates are microscopically examined to determine their make up (9:7-2). The usual price for a "Hi-Vol" is approximately $500 (4). Ease of operation and low unit cost are the major advantages of this unit. The major limitation of the "Hi-Vol" is that the filter itself adds particles to the sample; however, if the exact make-up of the filter is known, an accurate analysis of the collected sample can be made (9:7-2).

The tape sampler is used to determine the haze factor (coefficient of haze) caused by the suspended particulates. The equipment operates on the same principle as the high volume sampler except that the particulates are collected on special filter tape. Also, it has a timing device which can be pre-set so that the suspected peak periods of pollution will only be sampled (9:2-7). This allows for more accuracy than offered by the "Hi-Vol" sampler which usually operates on a 24-hour basis. The major disadvantage of the tape sampler is chemical analysis cannot usually be made because of the small quantity of particulates collected (9:7-3). This equipment is more expensive than the "Hi-Vol" sampler.

*Hydrocarbons*

The most widely used device to measure the atmospheric hydrocarbons is the flame ionization analyzer. The device has the major disadvantage in that it measures total hydrocarbons and not individual types of hydrocarbons or the hydrocarbon mixture (8:101). The cost of the equipment is approximately $1500 (9:7-5).

*Nitrogen and Sulfur Oxides*

These oxides are usually measured by the "bubbler" device because it is relatively inexpensive at a price of $300 (4). The basic principle on which this system operates is to bring an air sample into contact with a sensitive chemical which causes a color change in the chemical, proportional to the concentration of the pollutant in the air sample (2:212). This process is known as colorimetric. The major disadvantages of this device are the necessity of having experienced personnel to obtain readings of 90% accuracy and the suction device requires frequent calibration (2:212). A continuous sampler is also available to measure these oxides. The price of this type unit varies for $2000 to $8000.

*Photochemical Oxidants*

As stated previously, ozone concentration is usually measured to indicate the overall photochemical oxidants concentration. An acceptable device used to determine ozone concentration is the chemiluminescent analyzer.

> The analyzer contains a photomultiplier tube which detects the quantity of light produced when ozone in the sample and ethylene from a canister react within an enclosed chamber. The amount of light energy produced indicates the concentration of ozone, and therefore, the photochemical oxidant level (1:76).

Although this device provides very accurate readings, it has a drawback in that it required daily calibration with a constant ozone source (8:134). The chemiluminescent analyzer is normally sold for $4500 (4).

> In the US we pollute our air with over 280,000,000 tons of aerial garbage each year. This dirty air costs (the) U.S. over $16,000,000,000 a year (6:5-6).

> We were treating symptoms, not the disease (7)

## AIR QUALITY

People have a right to be concerned over the quality of the air; however, what is "quality air"? Air quality criteria asks the question of how clean should the air be? The answer is, the air should be clean enough so that there are no undue bad effects on people, animals, land, vegetation, buildings, etc. (3:253). Federal air standards were based on these criteria and are shown in Table 3. Primary standards provide for protection of public health; secondary standards provide for protection of public welfare and are more stringent than the primary standards (5). This brings out a typical problem in understanding air quality. Notice in that same table, the Ohio standards are not in complete agreement with the Federal standards. While much progress has been made in determining what is good air, this section will attempt to point out to the reader some of the difficulties which are encountered when trying to measure and report to the public, the air quality.

*Which Standard?*

Suppose you are reporting the effect of carbon monoxide on the air quality. During the day you made your measurements of the carbon monoxide concentrations and you got the following results:

1 - hour means = 50 micrograms/meter$^3$ (bad)

8 - hour means = 8 micrograms/meter$^3$ (good)

Was the air quality, due to carbon monoxide influences, good or bad?

| POLLUTANT | DURATION | RESTRICTION | OHIO STANDARDS Micrograms per Cubic Meter | FEDERAL STANDARDS Primary Micrograms per Cubic Meter | FEDERAL STANDARDS Secondary Micrograms per Cubic Meter |
|---|---|---|---|---|---|
| Suspended Particulates | Annual Mean | Not to be exceeded | 60 | 75 | 60 |
| | 24-hour concentration | Not to be exceeded more than once per year | 150 | 260 | 150 |
| Sulfur Dioxide | Annual Mean | Not to be exceeded | 60 | 80 | — |
| | 24-hour concentration | Not to be exceeded more than once per year | 260 | 365 | |
| | 3-hour concentration | Not to be exceeded more than once per year | — | — | 1,300 |
| Carbon Monoxide | 8-hour mean concentration | Not to be exceeded more than 1 eight hour period per year | 10 | 10 | 10 |
| | 1-hour mean concentration | Not to be exceeded more than once per year | — | 40 | 40 |
| Photochemical Oxidants | 1-hour mean concentration | Not to be exceeded | 119 | 160 | 160 |
| | 4-hour mean concentration | Not to be exceeded more than 1 consecutive 4-hour period per year | 79 | — | — |
| | 24-hour mean concentration | Not to be exceeded more than 1 day per year | 40 | — | — |
| Non-methane Hydrocarbons | 3-hour mean concentration | Not to be exceeded between 6 AM and 9 AM | 126 | 160 | 160 |
| | 24-hour mean concentration | Not to be exceeded more than 1 day per year | 331 | — | — |
| Nitrogen Dioxide | Annual mean | Not to be exceeded | 100 | 100 | 100 |

TABLE 3

Air Quality Standards (5).

*White Pollutant?*

Normally, after measurements of the pollutants have been made, the pollutant with the worst concentration in the ambient air is used to determine whether or not the air quality is acceptable. Shouldn't the possible synergistic effect among the pollutants be taken into account when determing the air quality? Common sense says it should, but unfortunately a device or chart(s) does not exist which would measure this effect.

*Where Do You Measure the Pollutants and What Pollutants Do You Measure?*

Economics play an important role in being able to accurately measure air quality. If unlimited resources (men, money, and equipment) are available, then the air quality for a large city could be measured as accurately as the current technology would allow. Unfortunately, state and municipal agencies, responsible for measuring air quality, are usually undermanned and do not have enough analyzers or the right type of analyzers, or both, needed to give an accurate assessment of the air quality for the area the agency is responsible. Under these restrictions, most agencies are forced to measure only those pollutants which pose the most serious threat to the air quality. Additionally, these agencies usually measure those pollutants based on population oriented sampling. This sampling technique attempts to locate analyzers where most of the people come into contact with known high concentrations of the pollutants in the ambient air.

*Inform the Public, How?*

Does John Q. Public really understand or even want to understand what "260 micrograms of sulfure dioxide per cubic meter of ambient air over the last 24 hours," means in terms of air quality?

In 1973, an Ohio Environmental Protection Agency engineer devised the Air Quality Index (5). The purpose of the index was to give the average Ohio citizen a number which he could relate to an air quality rating. Table 4 shows the basic ratings of the Air Quality Index (AQI).

> The AQI is designed to report air quality levels based upon the concentrations of four pollutants: suspended particulate matter, sulfur dioxide, carbon monoxide, and photochemical oxidants (smog). Recorded pollutant concentrations are converted from micrograms per cubic meter to a numerical equivalent on the AQU scale. . . . . The reported value always represents the highest daily reading recorded during the reporting period.
>
> The number 100 on the AQI scale represents the AIR QUALITY STANDARD for each pollutant which is not to be exceeded more than one time per year, . . . . Thus, whenever the AQI reported on a given day is above 100, it is possible that certain groups of people—asthmatics, emphysema patients, etc.—may suffer acute, short-term ill effects. As the index climbs higher, into the 200's and 300's increasingly larger segments of the population will similarly experience acute effects, ranging from discomfort to actual medical problems. Likewise, increasing AQI levels result in increasing damage to crops and materials.

TABLE 4

The Air Quality Index.

| *Index Value* | *Air Quality Rating* |
|---|---|
| 0-100 | Good |
| 101-199 | Poor |
| 200-299 | Alert |
| 300-399 | Warning |
| 400 | Emergency |

> An AQI value of 200 is considered the ALERT level. When this level threatens to continue for an extended period of time, . . . temporary production cut-backs by industrial sources of pollution and a curtailment of private auto use by area residents (is required). Public announcement of the ALERT is often necessary with an appropriate warning to area citizens regarding possible adverse health effects.
>
> At 300—the WARNING level—further industrial cut-backs are required and an updated report of the worsening situation will be broadcast.
>
> At 400, an air pollution EMERGENCY is declared. Air quality has deteriorated, at this point, to an extremely hazardous level which requires drastic and immediate remedial action. At the EMERGENCY level, industrial production ceases and vehicular traffic is prohibited with the exception of emergency-type vehicles.
>
> The restrictions imposed at the various stages—ALERT, WARNING and EMERGENCY—are removed as significant reductions in pollutant concentrations occur (1:11-12).

The AQI has shortcomings, one of which is the fact that is does not consider the synergistic effects of the pollutants. However, the AQI is a positive step in the direction of informing the citizens of the air quality in their area in non-technical terms. Table 5 is an abbreviated Ohio Air Quality Index. The times (e.g., 24-Hr.) identify the sampling durations.

> To obtain cleaner air - not air of pristine purity, just air that's safe enough to breath-are we prepared to accept changes in our lifestyles and values? . . . What price are we willing to pay for the public good? For communities no longer cloaked in shrouds of pollutants? For our own health (10:24)?

| Index | Susp. Part. (Ug/m³ ) 24-Hr. | Sulfur Dioxide (Ug/m³ ) 24-Hr. | Carbon Monoxide (Ug/m³ ) 8-Hr. | Ozone (Ug/m³ ) |
|---|---|---|---|---|
| 1 | 1 | 2 | 100 | 1 |
| 25 | 37 | 65 | 2500 | 29 |
| 50 | 75 | 130 | 5000 | 29 |
| 75 | 112 | 195 | 7500 | 89 |
| 100 | 150 | 260 | 10000 | 119 |
| 125 | 206 | 395 | 11750 | 139 |
| 150 | 262 | 530 | 12500 | 159 |
| 175 | 319 | 665 | 15250 | 179 |
| 200 | 375 | 800 | 17000 | 200 |
| 225 | 437 | 1000 | 21250 | 350 |
| 250 | 500 | 1200 | 25500 | 500 |
| 300 | 625 | 1600 | 34000 | 800 |
| 350 | 750 | 1850 | 40000 | 1000 |
| 400 | 875 | 2100 | 46000 | 1200 |

TABLE 5

Ohio Air Quality Index (1:87-91)

What should be done? Control of air pollutants and improvement of the air quality will have to come through the actions of three groups: government, industry and the public.

*Government (6:14)*

The Federal Government can help to control air pollution is the following ways:

1. Continue to do research to:

a. Discover the effects of air pollution on health, vegetation, buildings, land, food crops, etc.

b. Develop air quality standards related to the synergistic effect of pollutants.

c. Improve the equipment and methodology used to measure the air pollutants.

d. Develop and improve the methods of controlling the air pollutants.

2. Continue to give technical assistance to the agencies responsible for maintaining air pollution control programs. Continued financial assistance should also be offered.

3. Write and enforce laws which will bring about equitable and effective control of air pollution.

*Industry (6:15)*

Industries can help improve the air quality by:

1. Developing methods to extract sulfur from the fossil fuels.

2. Developing a pollution-free automobile at a practical consumer price.

3. Improving the efficiency of the combustion in engines, boilers, etc.

4. Developing alternate sources of energy which do not pollute the air.

*The Public*

John Q. Public also needs to be involved in the effort to clean up the air. He can:

1. Support the programs of the state, regional, and federal pollution control agencies.

2. Reduce his use of electricity.

3. Form car pools or use mass transit systems.

4. Walk or ride a bicycle instead of taking the car, whenever practical.

6. Demand positive action from his local, state, and Federal Government representatives, on the air pollution issues.

7. Contact Regional EPA when he needs help or answers on specific environmental issues (Table 6 lists the Regional EPAs).

During that one week. 4,000 persons are believed to have died as a direct result of air pollution (7).

## SUMMARY

There are six main air pollutants: carbon monoxide, particulates, hydrocarbons, nitrogen oxides, sulfur oxides, and photochemical oxidants. All of these pollutant's concentration, in the ambient air, can be measured with either simple or highly complex devices. The use of measuring devices is necessary to determine if the concentration levels are above or below air quality standards. Pollution control agencies have a common problem in trying to determine what place, when, and how a meaningful and representative measurement can be made. Agencies should also be concerned with finding an easy way to relate concentration level to air quality. The Ohio EPA developed the Air Quality Index to inform its citizens about the air quality.

Air pollution is everyone's concern. In order to control pollutants and improve the air quality, active harmonious involvement on the part of the government, industry, and the public is required.

| *Regional Office* | *States Covered* |
|---|---|
| Boston, Mass. 617-233-7223 | Conn., Me. Mass., N.H., R.I., Vt. |
| New York, N.Y. 212-264-2515 | N.J., N.Y. |

| | | | |
|---|---|---|---|
| Philadelphia, Pa. 215-597-9370 | Del., Md., Va., W.Va., D.C. | Denver, Colo. 303-837-4905 | Colo., Mont., N.Dak., S.Dak., Utah, Wy. |
| Atlanta, Ga. 404-526-3004 | Ala., Fla., Ga., Ky., Miss., N.C., S.C., Tenn. | San Francisco, Calif. 415-556 6695 | Ariz., Calif., Hai., Nev. |
| Chicago, Ill. 312-353-5800 | Ill., Ind., Mich., Minn., O., Wis. | Seattle, Wash. 206-442-1203 | Alaska, Idaho, Ore., Wash. |
| Dallas, Tex. 214-749-1151 | Ark., La., N.Mex., Okla., Tex. | | |
| Kansas City, Mo 816-374-5494 | Ia., Kan., Mo., Neb. | | |

TABLE 6

EPA Regional Offices (10:25).

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# CHAPTER II — AIR

## AIR POLLUTION CONTROL

By Mr. Gary Flottman

The twentieth century, and a new highly automated, industrial society brought on a problem the world had never faced before. From the stacks of trains, electric power plants, and industry come smoke and gases in unprecedented amounts. Automobiles and airplanes belched out sulfur and nitrogen oxides, and other pollutants.

The problem was not severe during the first forty years of this century but it continued to grow. Concern over air contamination began in 1907, with the formation of the Smoke Prevention Association, and in 1912, with the first governmental gesture toward control of air pollutants with the Bureau of Mines studies of smoke control (4; 2-1).

Then during World War II, new production plants for wartime greatly increased the amount of air pollution (4; 2-2). At the same time, Congress was too preoccupied with the war to pass legislation on the air pollution problems. And after the war, with wartime restrictions on production and buying of automobiles lifted, suddenly there were 300,000 new cars on the highway (4; 2-22, 23). This caused traffic jams in urban areas, immobilizing traffic, and pouring motor exhaust into the air in unprecedented amounts. The grave effects caused by motor exhausts on pedestrians, drivers, businesses, buildings, and city vegetation convinced many that smoke was not the only form of air pollution.

The first renowned congressional activity concerning the air pollution situation came in 1950. Two resolutions passed the House, asking for research, but died in the Committee on Interstate and Foreign Commerce. The same year, the American Municipal Association adopted its first resolutions on air pollution and began lobbying in Washington for air pollution control legislation (4; 2-23).

The United States Conference on Air Pollution, requested by President Truman, met in May, 1950. Over 750 people, representing government, industry, and civic groups interested in conversation and beautification met and passed a resolution asking the government to take the leadership in determining air pollution causes and developing techniques to control it (4; 2-23).

It was not until 1952 that an attempt was made to pass air pollution legislation in Congress. The House Interstate and Foreign Commerce Committee passed a resolution directing the Surgeon General, the Secretary of the Interior, and the Secretary of Agriculture to begin research within the scope of their existing authority. The House passed the resolution, but the Senate failed to pass it by one vote. Attempts to pass legislation concerning air pollution failed again in 1954, but later that year the Secretary of Health, Education, and Welfare established an Ad Hoc Committee with representatives of nearly all governmental departments and agencies concerned and the National Science Foundation. This Committee examined every facet of the air pollution situation and reported to President Eisenhower that in some areas, air pollution has reached the saturation point (4; 2-23).

In 1955, the President proposed strengthening programs for air controls in his State of the Union message. In the same year, he stated that air pollution was a serious health problem and asked for higher appropriations for the Public Health Service to gather more scientific data and find more effective air pollution controls (4; 2-23).

In April, 1955, the Senate Flood Control subcommittee of the Rivers and Harbors Committee considered the air pollution problem, but decided that it was a State and local problem and recommended the Federal Government keep its hands off (4; 2-23).

On May 31, by a voice vote, the Senate accepted the Committee's recommendations, including a $3 million annual appropriation for five years for air pollution control research. On July 5, the House passed a bill which raised annual funding to $5 million and said the Federal Government had a role in the enforcement of pollution controls. The next day, the Senate voted to accept the House version. The President signed the legislation on July 14, 1955, and it became Public Law 84-159. Until passage of the Clean Air Act of 1963, this remained the basic statute for federal air pollution involvement (4; 2-23).

From 1955 through 1962 there was growing interest. Demands for more and stronger legislation to reduce air pollution increased in the Congress and State legistlature. Little was done however, but the "urban lobby", composed of the United States Conference of Mayors, the American Municipal Association, and the National Association or Counties continued pressuring Congress for additional federal action (4; 2-23).

Most of industry, led by the National Association of Manufacturers, opposed any increase in the air pollution programs. To require them to control air pollution would be an economic burden upon them. The automotive, chemical, iron and steel, and coal industries voiced their opinions. The American Medical Association approved limited federal expenditures for research but felt that regulations on air pollution should be left to the state and local communities. The Association of State and Territorial Health Officers agreed. All agreed the federal role should be primarily in research and that regulation and enforcement should be left to the state and local governments (4; 2-24).

Then in 1962, Abraham A. Ribicoff was elected to the Senate. His first act was to introduce the "Clean Air Act" along with nineteen co-sponsors; the Clean Air Act was then managed by Senators Nueberger, Eagle, and Kuchel. This proposed legislation was debated, discussed, and revised throughout the year (4; 2-24).

In the House a bill was introduced on February 28, 1962, by Representative Ken Roberts and considered by the Committee on Interstate and Foreign Commerce. Roberts was Chariman of the subcommittee on Health and Safety and had been concerned with anti-air-pollution studies for years. The bill was revised after extensive hearings, and measures identical to the

Ribicoff bill in the Senate were tacked on (4; 2-24).

The Clean Air Act was adopted in December 1963, and with it came significant change in federal policy toward air pollution. The state and local governments were still to have the responsiblility for the control of air pollution, but the Federal Government was to aid state and local governments with financial assistance and stimulate them to increase their efforts toward air pollution control (4- 2-24) (1; 141).

The Federal Government was to directly aid in the development of state, regional, and local control programs to reverse the trend toward increasing pollution. The federal government, Division of Air Pollution, was given expanded authority for research, development, and technical assistance programs. Great emphasis was placed on the fact that there is much we do not know in the technical aspects of controlling air pollution. The Federal Government assumed the responsibility for seeing that this knowledge is developed.

In November of 1967, the Air Quality Act was signed into law by President Johnson (4; 2-30). This act provides a blueprint for dealing with regional air pollution problems. It calls for coordinated action at all levels of government, and industry. This legislation develops the combining of adjacent communities with a common air pollution problem into a region to develop and implement air quality standards.

The Air Quality Act of 1967, known as Public Law 90-148 had the following effects (1; 142): (1) The department of Health, Education and Welfare (HEW) supported national research and development, training, and demonstrates activities, giving grants and contracts to many kinds of individuals and organizations (including private industry). In particular, fuel evaporation and combustion processes were studied, (2) HEW was authorized to hold a conference on any potential air pollution problems These hearings were only advisory to the local agency, but became an official record for future abatement proceedings, (3) HEW made grants-in-aid to assist state or local pollution-control agencies, up to two-thirds of the cost of planning, development, and improvement and half that of maintenance. Multimunicipal (regional) agencies could obtain up to three-fourths the cost of agency establishment and three-fifths of maintenance costs, (4) Federal enforcement authority could be invoked against any air pollution that "endangers" health or welfare. Proof of actual injury was not needed. Federal authority is intended to be operational in interstate cases and is subject to state and local action within any state's boundaries. Enforcement is through two approaches; by conference or by application of regional air quality standards.

Then in 1970, a new set of amendments known as the Clean Air Act of 1970, were enacted into law. The chief provisions and effects of the new act are as follows (1; 146): (1) Nationwide, uniform air quality standards are set by Federal Government rather than by each state (guided by the Criteria), as under the earlier law, (2) All air-quality control regions under consideration (approximately 100) were established immediately and any residual geographic areas in a state that had not already been so constituted by virtue of the air shed concept were also designated as control regions (the right to redesignate these regions after further study is reserved, (3) It became immediately compulsory for each of the states to establish "implementation plans" to conform to the federal air quality goals (ambient standards) by a fixed date. The states still maintained the right—in fact, were required—to establish their own methods of reaching the goals, so long as they could show how they would succeed. In practice, the time period allowed to submit their plan was so short that the federal guidelines issued as "Regulations for State implementation Plans" were closely followed. In cases where the state control plan was deemed inadequate, the EPA administrator had the right to modify it or to substitute his own plan, thus assuming a certain degree of uniformity (55 plans were submitted by states and territories; fourteen were fully approved and the remaining were supplemented by the Environmental Protection agency administrative), (4) Federal control of automobile emissions by annual certification of new engine types was continued by the new law, (5) The authority to control vehicle fuel additives (such as lead and phosphorus in gasoline) that may be harmful to health was also included, (6) The law provides for two classes of national emissions standards. The first is for the emissions of new stationary sources categorized by the EPA as contributing significantly to air pollution. The second is for which no ambient air-quality standard is applicable and that may contribute to mortality or irreversible illness.

In addition to the above, other sections of the act are significant and worth noting. These included grants or funds for research, training, planning and control; provision for federal enforcement if the state plan fails; federal right of inspection, monitoring, and entry into stationary sources and the public availability of emissions records so obtained, except where they would reveal trade secrets; federal emergency powers to immediately restrain the cause of any air-pollution emissions that may be hazardous to health; right of citizen suits, including those against government or its agencies, if standards or limitations under the act are believed to be violated; and a requirement for continuing, comprehensive economic studies of controlling pollution to the government, industry, communities and others (1, 147).

## AIR POLLUTION CONTROL DEVICES

A. Electrostatic Precipitators. The basic elements of an electrostatic precipitator are a source of undirectional voltage, preferable with some ripple on it; a corona or discharge electrode; and a hopper to receive collected material. Three operations occur in electrical precipitation and they can occur simultaneously. They are: particle charging, particle collection, and transport of collected material. When they occur simultaneously they are often called single stage or Cottrell type. In some special applications—notably cleaning air for recirculation in occupied spaces—the process is conducted in distinct steps in separate sections. In either case the fundamental operation principles are the same (4; 5-16, 5-17).

Particle charging is achieved by the formation of an electrical plasma of positive ion-electron pairs in the region very close to the discharge electrode. This is commonly called the corona discharge. The corona discharge provides a source of unipolar gas ions which migrate out toward the grounded passive electrode—filling the interelectrode space with a unipolar space charge. Particles entrained in the gases passing through this space charge collect these gas ions and become

themselves highly charged. The same electric field that has produced the space charge them becomes the collecting field in which the charged particle is caused to migrate toward the passive or collecting electrode. Once the particle reaches the collecting electrode, it adheres to it until removed by mechanical means into the hopper below for storage and ultimate disposal (4; 5-17).

Three basic equations which govern electrostatic precipitators are (4; 5-18): (1) $Eff = \exp \frac{(-Aw)}{(V)}$, (2: $w = \frac{Eo\ Epa,}{2nn}$ (3) Eo, Ep = f (Pg, R); where Eff = fraction collected: A = surface area of collecting electrodes, V = Volmetric flow rate, w = particle drift velocity, E = charging field, volts/distance, Ep = collecting field, volts/distance, a = particle radius, n = gas viscosity, Pg = gas density, R = particle(s) bulk resistivity.

The efficiency is seen to be related to the total surface area of collected electrode per unit volume of gas treated, and the particle drift velocity. In all other particulate collection devices, it is necessary to accelerate the gas before separation can be obtained. The electrostatic precipitator, however, has the unique feature of applying the separating forces directly to the particles without the necessity of accelerating the gas. This results in an extremely low power input requirement for the collection of fine particles compared with any other form of collector (4; 5-17).

The electrostatic precipitator is sensitive to factors affecting the maximum voltage at which it can operate. These are principally the gas density and the electrical conductivity of the material being collected. The higher the gas density, the higher the particle drift velocity, w, and the higher the efficiency as long as the other parameters remain constant (4; 5-18).

Resistivity, R, is the reciprocal of electric conductivity. If the resistivity of the gas particles is too low, particles on reaching the collecting electrode rapidly lose their charge and can easily become reentrained in the gases. If the resistivity is too high, charged particles reaching the collecting electrode cannot lose their charge because of the low conductivity of the material deposited earlier. A large voltage gradient then builds up across the deposited layer, subtracting from both the charging and collecting fields and causing the particle drift velocity to fall off (4; 5-18).

If this process continues, a dielectric breakdown will occur and a phenomenon called "back ionization" or "back corona" which provides a source of ions of opposite charge to those generated by the charging electrode. These effectively neutralize the unipolar space and disrupt the process of collection (4; 5-18).

Because of their relatively low power input, because they do not rely on inertial separting forces, and because they can operate completely dry, electrostatic precipitators find their most prevalent use where (4; 5-19, 5-20): (1) Very high efficiencies are required on fine materials, (2) Volumes of gas are very large, (3) Water availability and disposal are problems, (4) Valuable dry material is to be recovered.

Initial cost for electrostatic precipitators in the 1,000,000 acfm (actual cubic feet per minute) is about \$0.50 per acfm. Operating cost and maintenance cost are each in the range of \$0.03 per year per acfm capacity (4; 5-20).

B. Cyclone Dust Collectors. This is one of the simplest types of particulate collectors. The gas stream enters, goes round and round inside the cone-shaped device, creating a vortex. The heavier particles fall to the outside due to centrifugal force and then down into a hopper. The remaining gases go to the center of the vortex and out the top (4; 5-7, 5-8).

Some cyclone collectors use a tangential entry of the gas to set up the vortex but in some cases, particularly multiple cyclones, turning vanes are used to turn the gas and create the vortex (4; 5-8).

The following equations govern the performance of all cyclone collectors (4; 5-9): (1)$V_t = k_1 \sqrt{\frac{\Delta P}{Pg}}\ Pg \times \frac{WP}{T}$. (2) $V_r = 2V_t{}^2\ (Pg - Pg)\ (a^2)$, (3) $Eff = f\ (V_r)$, (4) $Q = R_2\ V_t$. Where Eff fraction collected, percent, by weight: $V_g$ = radial velocity of particle, $V_t$ = tangential velocity of particle gas viscosity, $r_a$ = average radius of rotation, Pp = particle density, Pg = gas density, a = particle radius, Q = volumetric flow capacity, $k_1$, $k_2$ = constants dependent on design of cyclone, P = pressure drop (power input), W = molecular weight of gas, P = gas pressure, T = gas temperature absolute.

The tangential velocity, $V_t$, of the gas must be high. The gas must be accelerated by expansion of the gas through a pressure change to achieve this high $V_t$ (4; 5-8).

The efficiency of cyclone collectors falls off on particles below about 10 microns in diameter (4; 5-9). This leads to the combining of cyclone collectors with other collectors. Cyclones can be put on the line first to remove course particles, then a different kind of collector such as a baghouse, can remove the finer particles.

To increase the efficiency of the cyclone collector in collecting particles of less than 10 microns, the radial velocity of particle, $V_R$, must be maximized by decreasing the radius of rotation. To handle any significant flow, then many small cyclones are placed in an array (4; 5-8).

Cyclones are useful under the following situations: (1) Where course particles are involved, (2) Where concentrations are fairly high—above 3 grains/scf, (3) Where classification of entrained material is desired, (4) Where very high efficiency is not a critical requirement, (5) Where reduced stack capacity—which is primarily dependent of finer particle size fractions—is not a criterion, (6) As precollectors in conjunction with collectors that are more efficient with finer particles (7) Where temperature of the gas is high or low (8) Where high gas pressure exists.

Cyclones are low in initial cost. For small diameter multitude collectors in the 1000,000 acfm range the cost is about \$0.09 per acfm of gas treated. Operating cost runs about \$0.05 per year per acfm design capacity and maintenance cost about \$0.04 (4; 5-10, 5-11).

C. Baghouse Collectors. Baghouse collectors otherwise known as fabric filter collectors are in reality very large vacuum cleaners. The filters of various configurations are made of porous fabrics which can stand the thermal, chemical, and mechanical rigors of stack gases. The most usual form of fabric filter comprises a number of cylindrical bags. Particles suspended in the gas stream impinge on, and adhere to the filter medium and thus are removed from the gas stream (4; 5-13).

Basically there are two types of collecting modes. "Surface" filters are such that the first deposits of dust collected becomes the filtering medium for the succeeding particles. In this case, to a certain extent, dust on the fabric makes the collector more efficient (4; 5-13, 5-14).

The other type is known as "depth" filters. The filter medium is a felted fabric into which particles may penetrate but do not pass through because of the constricted tortuous path they would have to follow. The following equation applies to baghouse collectors (4; 5-14): $\Delta P = {}^{m}V_s\ (K_D + K_1 w)$. Where $\Delta P$ = pressure drop, $V_s$ = superficial velocity, $K_D$ = weave resistance coefficient (0.01 - 0.04) $K_1$ = cake resistance coefficient (shape, humidity), w = cake wt/sq. ft. surface, $\mu$ = gas viscosity.

Fabric filters have to be cleaned at intervals. Methods of cleaning are: mechanical shaking, collapsing, reverse flow, shock wave, pressure pulse, and others (4; 5-14).

Selection of the fabric to stand thermal and chemical conditions is critical. The maximum operating temperature attained to date are only 550 degrees to 600 degrees F (4; 5-16).

Baghouses are usually utilized under the following situations (4; 5-16): (1) Where very high efficiencies are required (99% +), (2) Where operation is generally above dew point, that is, low humidity in gases, (3) Temperatures are not excessive, (4) Volumes are relatively low and therefore scrubbers or precipitators are not normally used; fabric filters can be and have been built for very large volumes, (5) Valuable material is to be collected dry, (6) Water availability and disposal is a problem.

Initial cost for baghouses range from $0.50 to $1.20 per acfm capacity depending primarily on the filter medium. Operating cost runs about $0.07 per year per acfm and maintenance costs which consists principally of bag runs about $0.15 per year per acfm (4; 5-16).

D. Wet Collectors. There is a great variety of wet collectors known as scrubbers and there are many types and configurations. All, however, operate on the same basic principle. In a set collector, the primary aerosol particles are confronted with impaction targets, which can be wetted surfaces or individual droplets. In most high performance scrubbers, droplets are usually the impaction target, with solid or liquid surfaces acting as mist eliminators or demisters. Demisters perform the function of separating the scrubbing liquid from the gas stream. Performance capability requirement is less important in the demister because the liquid droplets with their capture particles have sufficient mass to have inertial separation. Demisters also cool the gases (4; 5-11).

The following equations hold for high energy wet scrubbers (4; 5-11):

(1) $\psi = 2/9\,(P_g - P_p)\,\dfrac{V_{RV}\ A^2}{\mu_g D_b}$

(2) $Eff = \exp(-KL\sqrt{\psi})$

(3) $D_b = f(\mu L, V_n, \sigma L, L)$

Where $\psi$ = impaction parameter

$\rho_p$ = paction parameter
$\rho_g$ = Gas density
$V_{RV}$ = relative velocity, particle to target
$V_N$ = atomizer nozzle velocity
a = particle radius
$\mu_g$ = gas viscosity
$\mu_L$ = liquid viscosity
$D_b$ = target diameter
Eff = fraction collected
L = liquid to gas ratio
k = constant
$\sigma_L$ = liquid surface tension

High-energy scrubbers are useful where (4; 5-12):

1. Fine particles must be removed at high efficiency.
2. Cooling is desired and moisture addition is not objectional.
3. Gaseous contaminants as well as particulates are involved.
4. Gases are combustible.
5. Volumes are not extremely high (because of relatively high operating cost per cfm).
6. Large variations in process flows must be accommcdated (Variable Orifice type only).
7. Relatively high pressure drop is tolerable.
8. The problem of scrubbing liquid polluted with the material (s) removed from the gas can be handled.

Initial cost for wet scrubbers in the 100,000 acfm capacity range, range from $0.30 per acfm in mild steel to $0.65 in stainless. Operating cost is relatively high, about $0.75 per year per acfm capacity. Maintenance cost is low, about $0.02 per year per acfm capacity (4; 5-13)

## CONTROL OF SULFUR OXIDES

Four ways to reduce sulfur oxide emissions from power plants are (2; 85): (1) Use low-sulfur fuel, (2) Shift to nuclear power, (3) Recover sulfur oxides as a useful product and market it, (4) Convert the sulfur oxides to solid form and dispose of it in as harmless a way as possible.

A. Stack Gas Removal Technology.

Stack gas removal of sulfur oxides is a relatively new development. Currently two techniques are in use, both utilize limestone. The choice is between injecting the limestone into the boiler or directly into the scrubber. The calcium in the limestone combines with sulfur oxides forming calcium sulfate and calcium sulfite (2; 86):

Boiler injection has the advantage: the resulting calcium oxide, carried into the scrubber with the gas, reacts more readily with the sulfur dioxide; thus a smaller and perhaps simpler type of scrubber can be used for the same degree of sulfur dioxide removal. Drawbacks are problems associated with dry grinding, the possibility of boiler fouling because the line lowers the ash flow temperature in the boiler, increased dust load on the scrubber, and increased sealing in the scrubber (2; 86).

Introduction of limestone directly into the scrubber gives the advantage of low-cost and pollution-free wet grinding, a less complicated situation in regard to retaining existing dust collection equipment, and less scaling in the scrubber. The slower dissolution rate of limestone, however, requires more holdup in the scrubber, which can be attained by various means, all of which are expensive (2; 86):

Practically any degree of sulfur oxide removal can be attained by limestone scrubbing (2; 87):

B. Removal of Sulfur Before Burning the Coal.

Sulfur is found in coal: (1) combined with the organic coal substances, (2) as an iron sulfide (Fe S2) in the form of pyrite or marcasite, and (3) combined as calcium and iron sulfate (2; 91).

Organic sulfur is chemically bound to coal in a complex manner, so that only drastic processes are sufficient to break the chemical bond, and these processes usually leave some end-product other than coal (2; 92).

Mechanical methods of cleaning involve separation of the coal from waste products as pyrite, shale, and roof-slate by utilizing difference in the physical properties—usually specific gravity of these components (2; 92):

Mechanical devices are divided into two general classes: wet (consisting of jigs, dense-mediua, concentrating tables, or flotation) and pneumatic cleaning. Most wet and pneumatic methods involve a stratification effect. In jigging, the raw-coal feed is agitated mechanically in a fluid medium to form layers of material, with particles of lighter specific gravity (coal) on top and progressively denser material underneath. By an appropriate slicing mechanism, the layers are separated into "clean" product and refuse (2; 92).

Technology for producing synethtic gas from coal has long been available. Synthetic gas in the past however had a low Btu value per cubic foot, in the range of 425 to 575. Natural gas however has a Btu per cubic foot value of about 1031. It is desirable to produce synthetic gas with a minimum value of 950 Btu/ct. ft.

Gasification is a process in which coal reacts with oxygen, steam, hydrogen, carbon dioxide, or a mixture of these to produce a pipeline product comparable to natural gas.

There are four major gasification processes. They are: (1) hydrogasification, (2) $CO_2$ acceptor, (3) molten salt, and (4) two-stage superpressure (4; 96):

The $CO_2$ Acceptor Process is based on use of high-calcium lime for heat transfer and for removing carbon dioxide from the product gas. Process steps include: (1) crushing and drying raw lignite, (2) devolatization and subsequent gasification of the lignite to produce a gas composed of methane, carbon dioxide and monoxide, and hydrogen in the right proportions for pipeline gas; and (3) purification and catalytic methanation of product gas to yield high-Btu pipeline gas (2; 97).

## ENERGY, POLLUTION, AND LIFE

Our society is an industrial society of affluence that is built around the extensive use of energy. It is impossible to change this overnight barring a catastrophe and neither do we want to change this. Rather our goal is to reduce air pollution through controls and changing to cleaner fuels.

Our ultimate goal must be to sustain life at the highest level possible and we must use our technology to find the best answers we can to the pollution problem.

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# CHAPTER III — WATER

## WATER BIOLOGY

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### *Water Biology*

Three-fourths of the earth's surface is covered with water, even a blade of grass is 90 to 95 percent water (1; vol. 19:229). Water along with air is probably the most taken-for-granted substance known to man. However, no life as we know it can exist without water. This chapter is dedicated to water, that molecular substance we know so much about and yet misuse so badly.

Almost everyone knows that a molecule of water consists of two part hydrogen and one part oxygen. It can be found in gaseous, liquid or solid states. Pure water is colorless, odorless, and tasteless. Water boils at 100 degrees Centrigrade (212 degrees Fahrenheit) and becomes a vapor. It forms ice at zero degrees Centigrade (32 degrees Fahrenheit). The measurement of heat (calories) is based on the amount of heat needed to raise the temperature of one gram of pure water from 14.5 degrees centrigrade to 15.5 degrees centigrade (1; vol. 4:142). The measurement of chemical acidity (pH7) or alkalinity (pH) is based on pure water which is neutral in alkalinity and acidity. The pH scales goes from one to fourteen with pure $H_2O$ having a pH of seven (1; vol. 14:463).

The basic reason pure water is rare is that most water in the natural state is teeming with minerals and organisms that give it color, odor and taste. Dissolved minerals such as the chlorides, magnesium and iron cause hardness which inhibits the lathering of soap and causes scale build-ups (1;vol.19:221). To innumerate the multitude of different species of flora and fauna that inhabit the waters of the earth is beyond the scope of this book. Water also contains dissolved gases such as carbon dixoide ($CO_2$), nitrogen and dissolved oxygen (DO). These gases, minerals and life forms are extremely important to the characteristics of water and its relationship to man.

Water will be discussed in three areas. The water or hydrologic cycle and its effects on life will be covered first. Water pollution, its causes and effects will be covered second. What man has done, is doing and can do about water pollution will be considered last.

### *The Hydrologic Cycle*

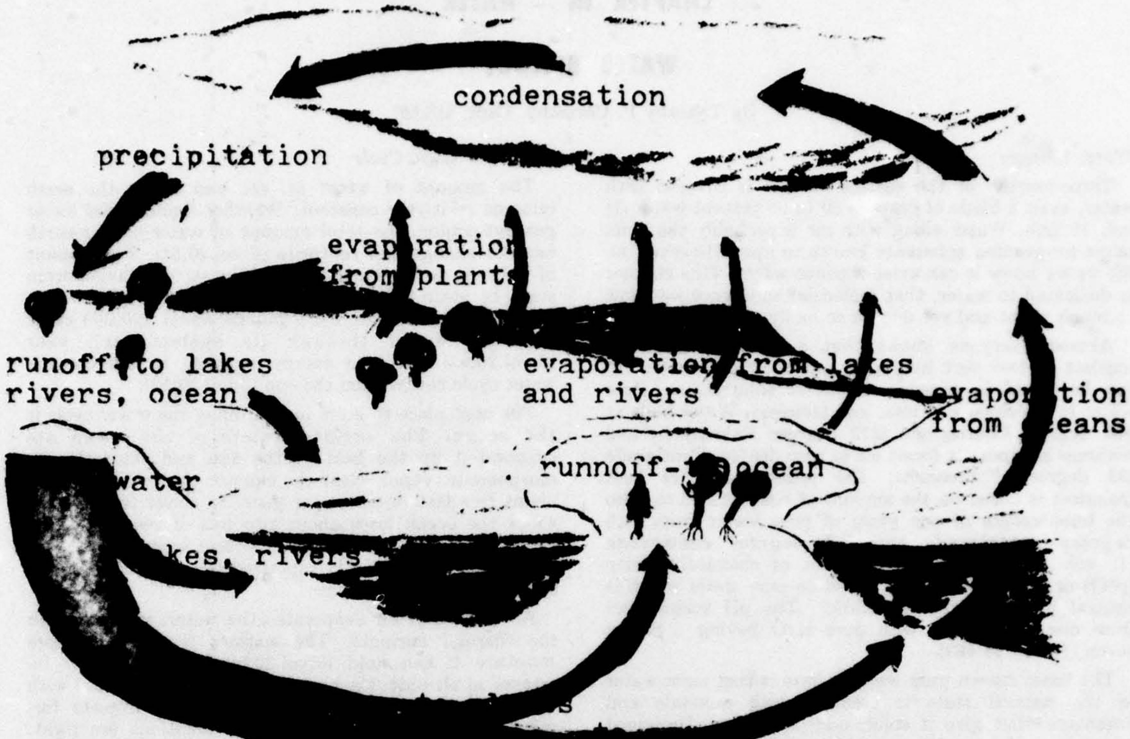
The amount of water in, on, and above the earth remains relatively constant. Whether liquid, solid ice or gaseous vapor, the total amount of water on the earth has not changed for centuries (6;vol.20:51). The amount of water in solid, liquid and gaseous states changes from state to state in what is called the hydrologic (water) cycle. The hydrologic cycle pumps about 100,000 cubic miles of water through its system each year (6;vol.20:52). All the energy required to operate the water cycle comes from the sun (6;vol.20:52).

The best place to start in describing the water cycle is the ocean. The surface waters of the ocean are evaporated by the heat of the sun and enter the atmosphere as vapor. Near the equator the ocean gives up about five feet of water per year. In cooler temperature zones the ocean loses about two feet of water per year (6;vol.20:52). An extremely important event takes place during the time water is vaporized in the atmosphere; it absorbs dissolved oxygen.

As the warm air evaporates the water, it raises with the thermal currents. The warmer the air the more moisture it can hold (6;vol.20:52). As the vapor increases in altitude, the air cools becoming saturated with water vapor—eventually condensing into droplets forming clouds (6;vol.20:52). If the conditions are right, the condensed liquid falls to earth in the form of rain, ice, snow, dew, or frost. The average amount of moisture returned to earth each year is equal to the average amount of water removed each year. Also note that the water also evaporates from lakes and streams as well as the ocean.

The water falls back to earth supplying moisture for plants and animals. Rain water is relatively free of minerals. It does contain suspended particles and some radioactive materials (2:89). Most of the water falls back into the oceans, but about 25,000 cubic feet of rain and snow per year falls on land (6;vol.20:52). The water is absorbed by the ground and eventually evaporates or finds its way to a stream, river or lake or ocean thus completing the hydrologic cycle.

## THE WATER CYCLE




(6; vol. 20:52)

Part of the water from dew, rain, sleet, etc. becomes ground water. As this water is absorbed by the ground it becomes either stored in ground pockets, absorbed by plants, channeled into streams or lakes, or evaporated from the top soil. Ground pockets may be underground caverns, wells or large rivers such as the Teays underground river of central Ohio.

River water continually erodes away the riverbeds, moving silt, sand, gravel and larger particles with the current. The rate of erosion depends upon the type of bottom material such as limestone, sand or mud, etc., and the rate of flow of the water (1;vol.16:86). River water in the United States supplies two-thirds of this country's household and municipal water. Three-fourths of the water used for irrigation and ninety percent of the water used by industry is also river water. Rivers are the source for hydro-electric power generation. Rivers such as the Ohio and the Mississippi are important transportation routes (1;vol.16:87).

River water quality differs greatly. Most rivers carry fresh water although some rivers pick up saline deposits from arid regions. The major minerals found in river water are calcium and magnesium salts. Organic materials carried in rivers are usually made up of microorganisms. This presents a health hazard as many organisms of this type cause disease. These organisms are introduced by direct dumping or accidental seepage of human and animal wastes into streams. This gives rise to pollution (1;vol.16:86).

Lakes are quite different than rivers. Most of the water dumped into lakes comes from rivers; however, the big difference between lakes and rivers is the flow of the water. Although most lakes have current flow, it is quite a bit less than that of rivers. In lakes the water may stagnate and the suspended particles and silt may settle to the bottom. This causes the lake to slowly fill. When a lake fills, this may take thousands of years depending on the size and depth of the lake; it becomes a bog, then a marsh, and finally the lake may become dry land. Lakes may present a problem to man as the slow movement of water may cause high concentrations of microorganisms. Lakes are also subject to thermal pollution or raising water temperatures.

Oceans are different from both lakes and rivers. They can be considered as a combination of salt lakes and rivers. Within oceans and seas are rivers of current such as the Japanese currents of the Pacific. Currents of this type move large amounts of water through the ocean while surrounded by lakes of slow moving water. Despite the fact that oceans are quite large they are subject to pollution, with man the major contributor.

### *Water Pollution*

Before discussing the bad qualities of our water, let us quickly review the sources of our water. We have already noted that we receive useable water from: (1) captured rainwater, (2) groundwater from springs and wells, (3) lakes and rivers, and (4) sea water. There is

also another source of water; the reclamation of wastewater (2:89). Each of these sources has their own benefits and disadvantages.

Rain water is fairly pure after its evaporation and aeration process. Groundwater is extremely pure, although it may be high in mineral content. Groundwater is slowly filtered through the soil. This removes pathogenic forms (disease causing organisms) and particles creating clear, colorless, and sometimes tasteless and odorless water (2:90). Groundwater is also easy to protect from the outside environment as it seeps deep into the earth's natural storage areas.

Surface water is a different story. The benefits and disadvantages varies with each separate lake, pond or river. This water is subject to misuse and contamination. It is sad to state that almost all the surface waters in the United States are contaminated and must be treated before it can be used for human consumption.

The largest water supply is the ocean. The drinking use of ocean water is limited due to high cost of desalting the water by distillation, electrodialysis, hyperfiltration and freezing (2:97). Presently, distillation of sea water is the only method in high volume use and is used on board ocean going vessels. The problem with desalination is the cost. The technology and the need have not developed yet to make desalination an economic and desirable process. Table 1 gives several examples of desalination taking place today (2:98).

TABLE 1

Examples of Each Principle Desalination Process in use, with Location and Production

| Process | Location | Production gal/day | Comments |
|---|---|---|---|
| Distillation | Kuwait | 18,000,000 | Oil center |
| Distillation | Israel | 1,000,000 | Arid region |
| Electrodialysis | Buckeye, Ariz. | 650,000 | Aird region |
| Electrodialysis | Webster, S. Dak. | 250,000 | Gov. research |
| Hyperfiltration (Reverse osmosis) | Plains, Tex. | 100,000 | Arid region |
| Direct freeze | Wrightsville Beach, N.C. | 200,000 | Gov. research |

No one wants to knowingly drink sewage water, but reclaimed wastewater is a useable source of water. Reclaimed wastewater is not commonly used for drinking; although it was used for that purpose at Chanute, Kansas with no ill effects (2:99). Irrigation, fishing, boating, swimming and washing are prime uses of reclaimed water (2:99).

Table 2 summarizes the quality of these sources. After these qualities are presented, the pollution of each source will be described.

TABLE 2

Quality Ratings of Raw Water Source Under Usage Conditions Prior to Treatment (2:102)

| | Quality factor | | | | |
|---|---|---|---|---|---|
| Source | Bacteriological | Physical | Chemical | | Hardness |
| | | | Toxic | Other | |
| Captured Rain | good | good | excellent | excellent | excellent |
| Surfacewater: | | | | | |
| Reservoirs | excellent | variable | excellent | fair | good |
| Lakes | good | good | excellent | fair | good |
| Rivers | fair-poor | variable | fair | poor | fair |
| Groudwater | excellent | excellent | excellent | fair | poor |
| Saltwater: | | | | | |
| Oceans, seas | good | good | fair | poor | fair |
| Brackish water | excellent | good | good | poor | poor |
| Reclaimed water: | | | | | |
| Domestic | poor | poor | good | good | good |
| Industrial | good | poor | poor | poor | variable |

### *Nature of Waste Discharge and the Effects on Water*

Generally, water quality is classified according to biologic, physical or chemical criteria as demonstrated in Table 2.

Pollutants are also classified as either degradable or nondegradable (3:14). Degradable wastes are those wastes that are broken down by biological, physical and chemical processes. The next time someone mentions biodegradable detergents, you will know what they are talking about—detergents that are broken down biologically in water. Nondegradable substances cannot be broken down from their present state when they come in contact with water.

Nondegradable substances are mainly inorganic (non-living), such as chlorides, synthetic organic chemicals, and suspended particles (3:15). Sources of nondegradable substances are industrial wastes, mineral mines, irrigated lands (salts and chemical fertilizers), and sea or brackish water intrusions into fresh water

Biological pollutants are perhaps the hardest pollutants to identify and the quickest to affect man. Long ago, the effects of water born pathogens were recognized. Pathogens are properly defined as parasites which try to locate in optimum living conditions within animals and man, and human pathogens are perhaps the more serious of the two. Man reacts adversely to all infectious human pathogens and to many of the animal pathogens.

Pathogens have difficulty surviving outside the body and surprisingly, fresh, clean, cool water is optimizing the habitat of pathogens outside the body. Table 3 identifies the conditions suitable for the existence of pathogens.

TABLE 3

Favorable and Unfavorable Environmental Factors for the Survival of the Pathogens of Man in the Free Environment (2:46).

| Favorable | Unfavorable | Comments on Survival |
|---|---|---|
| Moisture | Drying | Drying is adverse to survival |
| Low Temperature | High Temperature | Survive from 0-60 degree C |
| pH range 5-9 | Other ranges | Pure water has pH of 7 |
| Shade | Sunlight | UV light is adverse |
| Freshwater | Saltwater | High salt content adverse |
| Clean water | Polluted water | Competition in Polluted water |
| Sterile soil | Natural soil | Competition in nat. soil |

Note that clean, fresh water conditions are quite similar to those of the human body.

There are hundreds of known pathogens, but only a few create serious health problems. Salmonella typhosa, which causes typhoid fever can survive up to four days in river water and up to seven days in tap water. Vibrio cholera can last three days in river water but only two days in tap water, because cholera causing bacteria are more heat resistant than the typhoid bacteria (2:47). Other well known pathogens are Mycobacterium tuberculosis and Entamoebia histolytica (amoebic dysentery) which can last up to 153 days in water at 12 - 22 degrees C (2:48). Poliomyelitis viruses, infectious hepatitis virus, enterocytophogenic human orphan (ECHO), and Coxsackie virus are also found in water (2:51).

These bacteria and viruses have originated in human and animal waste. "About one-quarter of the 100 - 150 grams of feces produced per person per day is bacterial cells" (2:142). Coliform organism output is about 300 billion per day. A typhoid carrier will also discharge about 300 billion organisms each day, while an individual with hookworm may discharge up to 800,000 eggs daily (2:142). Table 4 shows the composition of sewage that is dumped into our waters. Note that inorganic substances are also dumped as sewage into water along with organic substances such as food waste and feces.

The organic sewage will be broken down completely as long as dissolved oxygen is present in water. This is called an aerobic process and must take place in the presence of oxygen (2:143). The products of the process are carbon, nitrogen, sulfur and phosphrous (2:143). Anaerobic decomposition takes place in the absence of oxygen. This is decomposition which causes strong odor, scum, and sludge in our waters.

TABLE 4

Approximate Composition of Medium Strength Domestic Sewage (2:142)

| Solids | In mg/1 Total | Organic | Inorganic | 5-day 20°C BOD,* mg/1 | of counts of coliform per 100 ml |
|---|---|---|---|---|---|
| Total | 800 | 450 | 350 | 200 | 100X10" |
| Suspended | 275 | 175 | 100 | 150 | |
| Settleable | 175 | 50 | 125 | 70 | 50X10" |
| Nonsettleabl | 100 | 70 | 30 | 80 | 50X10" |
| Dissolved | 525 | 275 | 250 | 50 | |

* Note: Biological Oxygen Demand of organisms in water.

Living organisms also feed on sewage (2:144). Phytoplankton through the process of photosynethesis breaks waste down to usable glucose. Zooplankton also feed off of waste material and the phytoplankton. This also helps rid water of organic wastes.

One major water pollution that may occur is that not all organic substances are completely decomposed. Phosphates and nitrates build up in the water and cause eutrophication or a nutrient buildup. As nutrients build up, they require more and more oxygen (biological oxygen demand) which robs the oxygen from higher life forms thus decreasing the number of higher life forms in the water (2:125). Wash off from fertilized fields, laundry detergents and sewage treatment operations cause phosphate and nitrate buildup (2:125).

Other pollutants should definitely be mentioned. Heavy metals are found in our water. Copper, mercury, lead, zinc, cyanide, etc., are residues from weed killers, pesticides and other toxic chemical compounds (2:125). These metals and other substances such as DDT settle in living tissue and remain there for prolonged periods of time. As they are absorbed by small organisms, small concentrations build up. As larger organisms feed on the smaller ones, the concentrations of the compounds increase. At the very top of this toxic buildup is man. Figure 2 shows the buildup of DDT in plant and animal life up to and including birds.

Unfortunately, the pollutants we have covered cannot easily be seen, except for the solid sewage. Garbage can easily be seen. We have used our waters as garbage dumps ever since we have had garbage and water. Our oceans are no exception to this rule. We have considered the ocean as a vast dump with no cost involved in its use (4:59). Recently oil spills have become an unsightly problem in our oceans. Large oil spills have occurred off England's coast as well as off California's coast (8:867). At the Golden Gate Bridge in 1971, two tankers collided spilling 840,000 gallons of oil in the bay (8:868). Santa Barbara suffered an oil spill in 1969 (8:881). Oil has caused the death of thousands of water fowl, fish and other aquatic lifeforms.

Water pollution has caused disease, death and even fire as in the case of the polluted Cuyahoga River in Ohio that caught fire in 1969 (9:743). The problem of water pollution must not be allowed to continue. Man cannot survive without abundant fresh clean water. What can be done to stop water pollution? The next section deals with man's efforts to clean the waters of the earth.

*Water Pollution Treatment*

Water treatment is quite simple if you want to take the time to boil your water each time you want to use it. Besides boiling water, we have learned to aerate it to achieve purity and kill pathogenic bacteria. Chlorination is a process used throughout the United States and many other countries. Basic water treatment in municipalities treating water consists of screening out heavy particles from raw water, filtering the water and chlorination.

Figure three shows the exact processes that occur in many water treatment plants. The process includes aeration, flash mixing, flocculation, settling, filtration and chlorination.

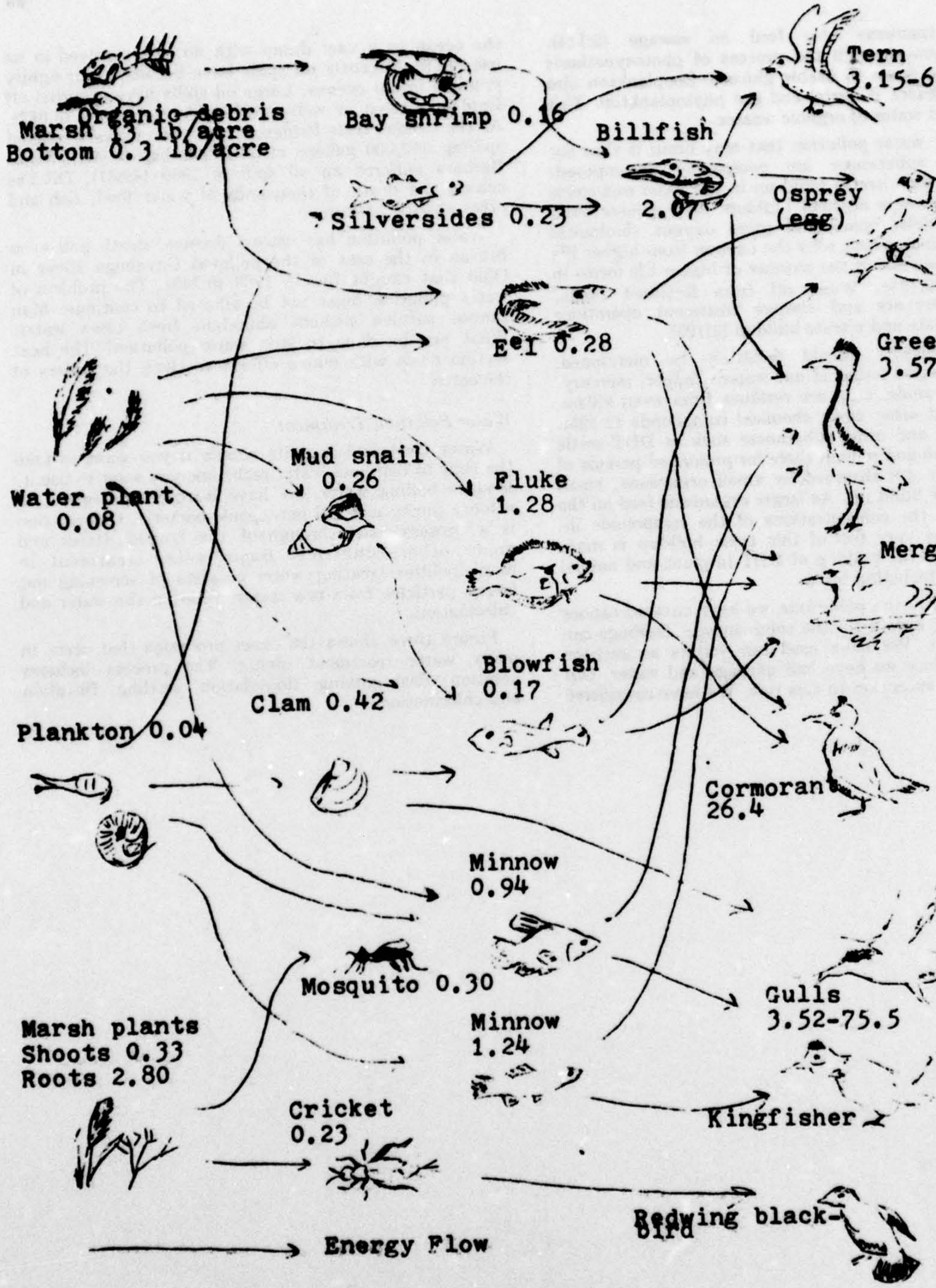



**Figure 2. Portions of a food web showing the concentrations of DDT in milligrams/ kilogram in each organism. (2:26)**

Aeration is the process of increasing the amount of dissolved oxygen in the water. Aeration also reduces the taste and odor of the water and oxidizes any soluble iron (2:108). Aeration may be accomplished by simply spraying the water into the air or by bubbling air into the water.

The flash mixing process pumps a coagulant, usually alum ($Al(SO_4)_3 \cdot 18H_2O$) into the aerated water (2:109). This causes the coagulation of suspended chemicals that can then be removed through the flocculation and settling process.

Raw $H_2O$

$\downarrow$

Aeration spray, or mechanical

$\downarrow$

Flash mix

$\downarrow$

Flocculation of coagulated $H_2O$

$\downarrow$

*Settling*

$\downarrow$

Filtration

$\downarrow$

Clear well

**Figure 3. Flow diagram of water treatment process (2:108)**

Flocculation is a gentle mixing of the water as the coagulation process takes place (2:108). The process allows the coagulated material to completely form in strings called floc. Iron, manganese, calcium, and magnesium are moved by this process.

Given time, a settling process takes place. This sedimentation is purely a gravity process. The floc slowly settles to the bottom and is removed from the water (2:110). During this process the water is moving slowly through a filter.

Filtration is the last process before chlorine is added to the water. Sand is usually the filtering agent (2:111). By filtering water through several feet of sand and gravel, many residues that have passed screens, coagulation, and sedimentation are removed from the water.

Chlorination is the final process. First used in water systems in 1908, it has been recognized as an effective bacteria killer (2:115).

Treating drinking water is not the real problem; it is the treating of waste materials that is the problem. The cause of the problem is mostly economic (3:71). The technology needed to clean waste water is known, the cost involved in applying this technology is rather large. More technicians, laborers, and materials are needed to effectively treat the waste water. Laws have been established to prevent raw sewage being dumped into waterways, but again economic problems prevent 100 percent compliance.

The use of biodegradable detergents has been urged by environmentalists (7:162). This allows complete oxidation of detergent compounds and rids the waters of organic materials and excess neutrients.

Private groups have taken serious interest in the water problem. Such organizations as the Sierra Club (5) have urged the organization of groups to clean up the water. The government is studying pollution problems and possible solutions to those problems. For further details, the following chapters give detailed information on the treatment of sewage and solid waste.

*Conclusion*

Our water is a precious resource. We must take care to clean and maintain this resource. In order to enjoy the benfits such as swimming, fishing, boating and drinking everyone must be concerned. We have recognized the sources of water pollution. The results of the pollution are plain. Since our existence we have shown little concern for clean water because we have so much. Now we must take action to prevent further polluting.

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# CHAPTER III — WATER

## SEWAGE & TREATMENT

By Allan K. Bean, Capt, USAF

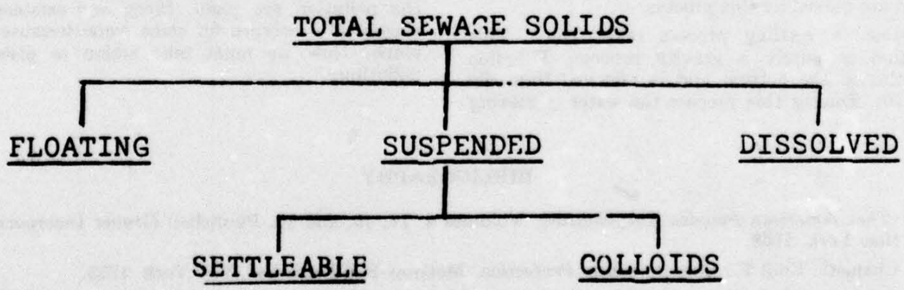
Let us take a look at the terminology that is used in the sewage and sewage treatment field. Domestic sewage will be the type sewage discussed unless specific reference is made to the other types—industrial or farm, etc.

*Sewage*

It is "the liquid waste of the community [8:9.1]." Sewage in the U. S. normally contains 0.1 percent solids with the remaining 99.9 percent being water (7:444; 8:9.1). However, the small amount of solids which are in suspension or else in solution present the greatest problem. Physical characteristics which may be used to describe sewage are temperature, color, odor, and turbidity. The normal temperature of sewage is slightly higher than that of the water supply used; however, more importantly, the temperature of the sewage affects the biological activities that take place in the sewage (2:340). The color of fresh sewage is gray, becoming darker to black as the sewage becomes stale or septic (2:340). The odor of fresh sewage is nearly odorless, perhaps having a slightly soapy or oily smell (2:340; 7:444). "Rotten or putrid odors, such as those of hydrogen sulfide [rotten eggs], and of indole, skatol, and of other products of decomposition, indicate a stale, septic sewage [2:340]." Normally, sewage is turbid, where higher turbidity results with higher concentrations of sewage (2:340). The concentration of sewage is frequently referred to as "strength, the stronger sewage having a greater proportion of putrescible compounds [7:444]." Sewage contains organisms transported in human feces which transmit diseases such as those that have been discussed in previous chapters. Untreated raw (fresh) sewage has a high Biochemical Oxygen Demand (BOD) and nutrients which can cause excessive growths of algae and other aquatic plants (3:142-144; 6:390-391). The disease carrying organisms, BOD and nutrients comprise the basic pollutant effects of sewage when, if untreated, are emptied directly into streams or on the ground such that the sewage enters water wells or goes beneath the water table. One additional pollution caused by raw sewage is the foul odor which occurs as the organic components in the sewage decompose and the sewage becomes stale or septic.

*Sewage Solids*

The solid organic and inorganic matter is either in suspension or else in solution in the sewage (7:444). A number of terms are used to specify different portions of the solids. Babbitt and Baumann use the terms volatile and fixed solids; the volatile solids being primarily the organic matter and the fixed solids being the inorganic matter (2:342-343). Further, the terms "suspended", "dissolved," "settleable," "colloids," and "floating material" are used to describe sewage solids (2:342-343; 4:103-105; 7:444-445; 8:9.38-9.39). "Suspended solids are those which can be filtered out on an asbestos mat and dried. They are relatively high in organic matter [7:445]." Dissolved solids are relatively low in organic matter and are those solids which are obtained from the evaporated sewage that has been filtered to remove the suspended solids (7:445). "Settleable solids are those suspended solids which will settle in sedimentation tanks in the usual detention periods [7:445]." Colloids are the suspended solids which "are so finely divided that they will not seetle [7:445]." The floating material is usually comprised of such items as "matches, paper, sticks and feces [8:9.38]." Figure 1 shows a diagramatic representation of these terms and their relationships to each other.




Note: All of these solids contain organic (volatile) and/or inorganic (fixed) matter in differing proportions.

**Figure 1. Relationship of Sewage Solids Terms**

Within the total sewage solids, normally half of the solids are organic and half are inorganic matter (8:9.38). The organic half of the solids are putrescible and as decomposition by bacteria progresses, the sewage beings to smell like the average person normally expects sewage to smell. One of the primary objectives of sewage treatment is the removal of the sewage solids and stabilization of the organic matter.

*Stabilization*

The organic matter in the sewage is stabilized when it "has been broken down by bacterial action to simple substances that will decompose no further [7:447]." There are two conditions of bacterial actions which take

place (1) aerobic and (2) anaerobic, although the two do not always occur separately (2:360). Engineering guidance on the degree of stabilization to be achieved has in the past been based primarily on cost economic considerations which included the ability of the waste disposal medium (stream, river, lake, land) to recover from the pollution before it is required for further use by man.

*Aerobic Stabilization/Aerobic Bacteria*

Aerobic stabilization is the stabilization of sewage solids by aerobic bacteria. Aeobic bacteria are nonpathogenic bacteria which require atmospheric oxygen or oxygen in solution in water to live and feed on the sewage solids to thereby decompose the solids. Aerobic decomposition of sewage solids does not produce foul odors and decomposes the solids within hours. This is significantly faster than anaerobic processes. The use of aerobic bacteria is one of the basic methods used in the conventional treatment of sewage to reduce the pollutional effects of the sewage. The aerobic process can be stopped, though, by an interruption or an inadequate supply of oxygen. If this occurs, then the stabilization process will revert to an anaerobic process (2:358-360; 4:105; 7:447-448; 8:9.41). The important point to remember is that this process is a biological process and that an influx of contaminates may temporarily upset the process or kill the bacteria and stop the process entirely.

*Anaerobic Stabilization/Anaerobic Bacteria*

Anaerobic stabilization is the stabilization of sewage solids by anaerobic bacteria. Anaerobic bacteria are nonpathogenic bacteria which live when there is no atmospheric oxygen or oxygen in solution in the water and feed on the sewage solids, thereby decomposing the solids. Anaerobic decomposition of sewage solids produces foul and unpleasant odors and requires several weeks to months to decompose the sewage solids, a significantly longer time than aerobic decomposition. "A sewage which has become dark and evil-smelling as a result of anaerobic decomposition is frequently called 'septic' [4:105]." The use of anaerobic bacteria is also a basic method used in the conventional treatment of sewage to reduce the pollutional effects of the sewage. A significant by-product of anaerobic processes is the production of gases. Two gases deserve consideration (1) hydrogen sulfide and (2) methane. The hydrogen sulfide has an unpleasant odor, is toxic in high concentrations, and attacks cement and certain metals in the presence of moisture. The methane is a highly violatile and dangerous gas. However, the methane may be used as a fuel to produce heat for obtaining desired temperatures of the sewage and sewage solids to aid in various sewage treatment processes (2:358-360; 4:105; 7:447-448; 8:9.41).

***Pathogenic Organisms***

**Human excreta may contain disease causing organisms usually referred to as pathogenic organisms. A sewage which is composed of the discharge of many persons will be likely to contain at least some types of pathogenic organisms. The pathogenes "usually present in sewage include the causal organisms for intestinal diseases such as typhoid, dysentery, diarrhea, etc. [8:9.41]." Sewage or even biologically treated sewage may contain pathogenic organisms; however, sewage does not provide a favorable environment for pathogenic** organisms and while the time required is not clearly known, they all appear to die out after a period of time. This time period ranges from several days to perhaps several months depending on the particular pathogenes, the relative pollution of the medium (stream, river, lake, land) and temperature. The important point to note is that the biological treatment of sewage provided by conventional sewage treatment does not remove all the pathogenes and the sewage must be disinfected, normally by the use of chlorine, prior to ultimate disposal (4:107).

*Coliforms*

Coliforms are a group of bacteria that are found in sewage. One type, *Escherichia coli* (E. coli), is among the group of coliforms and is one which "normally inhabits the intestines of man and animals and is excreted with the feces [4:106]." Coliforms, including E. coli, are not considered to be pathogenic organisms. When coliforms and pathogens are present in sewage, the coliforms will be present in significantly higher concentrations than the pathogens. The E. coli are important as indicators of the amount of contamination in the sewage, especially that due to the pathogenic organisms. Sewage does not provide a favorable environment for E. coli; they are not able to reproduce and they die out at rates dependent upon environmental factors which are very similar to the pathogenic organisms (4:105-107). Tests of the amount of E. coli in the sewage therefore provide a good estimator of pathogenic organisms in the sewage. The point to remember is that E. coli, themselves, are not the dangerous contaminant in sewage or treated sewage, but only provide for a means of indirectly measuring the amount of pathogenic organisms which may be present.

*Sludge*

The sewage solids which are separated from the sewage at any stage in a sewage treatment process and collected in a sedimentation tank are called sludge. These solids normally contain a very high moisture content, usually greater than 94 percent. Since sewage solids may be separated from the sewage by different stages or processes during sewage treatment, different names for the sludge obtained may be encountered. The name that is used will often indicate the process from which the sludge was obtained and the meaning of the term can be determined within the context of the subject being discussed. Several common examples of types of sludge referred to in the literature are presedimentation sludge, activated sludge, trickling filter sludge, chemical precipitation sludge, and digested sludge. The disposal of sludge creates the most serious potential pollution problems because the concentration of sewage solids is greater than the concentration of solids in the effluent from the process producing the sludge. Approximately 60-70 percent of sludge solids are organic matter. This organic matter, as discussed under the heading of *sewage solids*, should be decomposed by the sewage treatment process although this is not always done (2:566-580; 7:572-596; 8:9.83).

*Sewage Treatment*

"Sewage treatment covers any artificial process to which sewage is subjected in order to remove or alter its objectionable constituents so as to render it less dangerous or offensive [7:333]." Sewage treatment

methods for individuals, for municipal services and future developments in sewage treatment are discussed in later sections; however, a brief discussion is provided here to fulfill the objectives of providing a handy reference for the student. "It is usually necessary to provide partial or complete treatment of sewage before it can be disposed of . . . [7:460]." "Sewage is treated to protect public health, to avoid nuisance, to prevent the pollution of natural waters and of bathing beaches, and to avoid damage suits [2:323]." Compliance with recent Federal and State laws concerning pollution and the awakened environmental awareness of the American public has provided additional reasons for treatment of sewage prior to disposal. Sewage treatment basically compresses "in time and space in a series of one or more sewage treatment unit process [3:150]" the natural processes of the self-purification which a stream, river or lake undergoes when polluted by raw sewage (3:150). The processes are the settling of suspended sewage solids with aerobic and anaerobic decomposition of both the settled solids, the dissolved solids, and the colloidal solids (3:150-151). Sewage treatment provided may range from provisions for only settling of suspended sewage solids to nearly complete purification of the sewage through application of all the natural processes with the additional use of chemical and mechanical processes (3:150-151). In the 1969 report to Congress on *The Cost of Clean Water and Its Economic Impact*, it was concluded that "over 90% of the sewered population of the United States is currently connected to waste treatment plants, and about 60% is served by secondary waste treatment [9:6]." It further states that

> It has been national policy that—with specifically defined exceptions—all sewered wastes should receive secondary treatment, that is, that they must undergo a biological process to stabilize the major part of the suspended and dissolved organic matter remaining in the waste stream after primary treatment [9:42].

In a recent text, it is stated that "at present, municipal waste water is usually given varying degrees of treatment before being discharged into receiving stream [6:344]." The text further points out that conventional sewage treatment processes can be made to perform better with continually advancing technological improvements in the state-of-the-art (6:344-404).

*Sewage Disposal*

This term "applies to the act of disposing of sewage by any method. It may be done with or without previous treatment [7:333]." Typical sewage disposal methods include disposal into bodies of water or on land of treated or untreated sewage. Disposal into bodies of water such as lakes, streams, rivers or oceans is known as dilution. Disposal on land is sometimes referred to as irrigation; the primary beneficial use coming from the water content of the sewage since the nutritional value of sewage is not very high. Methods of disposing of sewage solids from treated sewage are burial, incineration, dumping or piping into the ocean, land fill, or fertilizer (2:1-2, 364-396; 4:140-144; 7:333, 461-462).

## SEWAGE TREATMENT METHODS FOR INDIVIDUALS

This section presents a brief discussion of the various types of sewage treatment methods that are used for treatment of sewage by individuals—homeowners, rural schools, etc.—when municipal systems for collection, treatment, and disposal of sewage are not available. It should be noted that although these methods for individual sewage treatment are available that they are not necessarily used and raw sewage is dumped into the most available medium. As Ehlers and Steep point out, even when they are used,

> too often the means of disposal to be used are a mere afterthought, to be solved by the digging of cesspool or the building, by a local workman who knows nothing of the principles of sewage treatment, of a septic tank that permits the septic effluent to run to any ditch or stream [4:111].

It is not our intent to provide you with the principles of sewage treatment so that you know how to build, but rather, a knowledge of what is available and recommended or not recommended for use. Regardless of the method used, usually little attention is given the system once in place; therefore, the system installed should be built such that as little maintenance as possible will be required (4:112). The systems or methods available are (1) cesspools, (2) septic tanks, (3) Imhoff tanks, and (4) Privies and retention containers. The cesspool can be described simply as the reverse of a water well. Untreated sewage is piped into a hole in the ground. The sewage then seeps into the ground. As a rule, numerous disadvantages are associated with cesspools which far outweigh the advantages. Consequently, cesspools are not recommended as a method for sewage treatment and disposal (4:112).

The septic tank is easily constructed and requires little maintenance. Sewage enters the tank where it should sit undisturbed for approximately 24 hours. The settleable sewage solids fall to the bottom of the tank and are decomposed by anaerobic bacteria. The remaining liquid sewage effluent is then piped into the soil where the soil filters the liquid and aerobic bacterial action decomposes and stabilizes the organic matter in the liquid sewage. The sludge buildup in the bottom of the septic tank must be cleaned or pumped out periodically. A septic tank system is satisfactory for general use (2:182-186; 4:112:131; 8:9.96-9.98).

An Imhoff tank is a variation of the septic tank. Basically, the Imhoff tank uses two chambers instead of one chamber as with the septic tank, allowing settleable sewage solids to settle out. The lower chamber collects the settled solids where anaerobic action occurs, thereby better assuring that the sludge is not disturbed during this process compared to the septic tank. The Imhoff tank is satisfactory for general use (4:112-131).

The pit privy—the little house out back—when properly constructed and maintained can provide for satisfactory sewage disposal. Other types of privies are the vault privy, the septic privy, and the chemical toilet. The vault privy, although used extensively from ancient times until recently, is not recommended for use today. The septic privy was not used widely and also does not provide a very satisfactory solution for sewage treatment and disposal. The chemical toilet is useful. The chemical toilet consists of a toilet seat located on top of a tight tank. The tank has 10 to 15 gallons of water in which 25 pounds of caustic soda has been dissolved which stabilizes the sewage (4:146-150). The use of caustic soda chemical toilets did not become widespread in the United States; however, variations of the chemical tank are used today in airplanes and boats in which "a com-

bination of emulsifiers and deodorants permit the recirculation of small quantities of water through a self-contained fine screening and flushing system [3:182]."

## MUNICIPAL SEWAGE TREATMENT

Because of the larger scale of the operation, municipal sewage treatment can provide more sophisticated and complete treatment of sewage than that performed by individual sewage treatment methods, although treatment is based on the same principles employed by the individual treatment methods. Municipal sewage treatment is usually classified into primary, secondary, and further treatment categories. Primary treatment usually refers to "those methods which remove a part of the suspended and floating solids [7:460]." Secondary treatment is normally preceded by one or more of the primary treatment methods and is used to "provide some means of satisfying oxygen demand [7:460]," usually through aerobic or anaerobic bacterial actions which decompose and stabilize the sewage and sewage solids prior to disposal. Even when both primary and secondary treatment are provided, the sewage is not completely treated. Further treatment is provided by chlorination to disinfect the effluent before disposal. Additional treatment may be provided as needed to eliminate or reduce the following pollutants before disposal: (1) plant nutrients from nitrogen and phosphorous compounds, (2) synthetic organic chemicals such as detergents, (3) inorganic chemicals and minerals, (4) radioactive material, and (5) heat. Steel has prepared an outline which concisely displays the common methods of sewage disposal and treatment and methods of treating and disposing of sewage solids (7:461-462), see figure 2, 3, 4, and 5.

I. Dilution or disposal into water
II. Irrigation or disposal on land
  A. Application to surface
  B. Subsurface irrigation

**Figure 2. Methods of Sewage Disposal***
*** Modified from Steel (7:461).**

I. Primary treatments
  A. Removal of floating & coarse suspended solids by
    1. Racks
    2. Medium screens
    3. Grit chambers
    4. Skimming tanks
  B. Removal of fine suspended solids by
    1. Fine screens
    2. Sedimentation by
      a. Plain sedimentation tanks
      b. Septic tanks
      c. Imhoff tanks
      d. Chemical precipitation tanks
II. Secondary treatment providing oxidation by
  A. Filters
    1. Intermittent sand filters
    2. Contact filters
    3. Trickling filters
  B. Aeration
    1. Activated sludge
    2. Contact aerators
  C. Chlorination
  D. Oxidation ponds
III. Further treatments
  A. Chlorination
  B. Other treatments for specific pollutants

**Figure 3. Methods of Sewage Treatment***
*** Modified from Steel (7:461).**

I. Screenings
  A. Medium screenings by
    1. Shredding and digestion
  B. Fine screenings by
    1. Digestion

II Settled solids (sludge)
  A. Primary-treatment and humus-tank sludges by
    1. Digestion
    2. Conditioning
      a. By elutriation
      b. With chemicals
    3. Vacuum filtration
    4. Drying
      a. On beds
      b. In kiln driers
  B. Excess activated sludge by
    1. Thickening
    2. Digestion
    3. Conditioning with chemicals
    4. Vacuum filtration
    5. Drying (as primary sludges)

**Figure 4. Methods of Treating Sewage Solids***
*** Modified from Steel (7:461-462).**

I. Screenings
  A. Medium screenings by
    1. Burial
    2. Incineration
  B. Fine screenings by
    1. Burial
    2. Incineration

II. Sludges
  A. Wet sludges by
    1. Dumping at sea
    2. Piping to sea
  B. Dried or dewatered sludges by
    1. Incineration
    2. Use as fertilizer
    3. Use as fill material for low ground

**Figure 5. Methods of Disposal of Sewage Solids***
*** Modified from Steel (7:462).**

A technical description of the operation of the various techniques used in primary, secondary and further treatment stages is not provided here, since it is felt that the information would be of little benefit to the management student. If the student understands the terminology and discussions presented in the first section of this chapter and the basic descriptions of individual and municipal sewage treatment and disposal systems discussed in the second and this, the third section of this paper, then he should be sufficiently prepared as a manager to make decisions which may directly or indirectly affect sewage, its treatment and its disposal.

## FUTURE DEVELOPMENTS AND SUGGESTED TOPICS

Sewage treatment and disposal is not a stagnant science. Considerable research and experimental work continues to be performed to improve the state-of-the-art. Better control and utilization of the conventional biological processes (aerobic and anaerobic) are being

pursued. Physical-chemical treatment methods are being investigated for use with or in lieu of conventional methods. Examples of the physical-chemical processes are the use of (1) absorption on granular or powdered activated carbon, (2) microscreening, (3) diatomaceous earth filtration, (4) chemical clarification, (5) oxidation, (6) foam separation, (7) distillation, (8) electrodialysis, (9) freezing, (10) ion exchange, (11) reverse osmosis, and (12) various techniques for removal of nitrates, phosphates, and ammonia (6:344-404). Further, there are recoverable constituents in sewage and other products of value which can be recovered from sewage such as fill material, methane gas, vitamin $B_{12}$, and yeast for use as animal feed (2:324; 10:47-50). Public law, PL92-500, promises to produce additional changes in the way publicly-owned sewage treatment facilities are constructed and operated in order to meet the interim treatment requirements established by the EPA for 1977 and 1983 and ultimately the discharge limitations which must be met by 1985 under PL92-500 (5:35).

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# CHAPTER III — WATER

## INDUSTRIAL WASTES AND TREATMENT

By John P. Donnellan

*Introduction*

This chapter will mainly deal with the effect industrial wastes have on streams (Section I) and treatment of the three major classifications of industrial wastes (Section II). The solutions to problems of stream pollution are many and varied. In most cases, however, the well informed chemical and sanitary engineer should have little difficulty dealing with these problems (7:3).

### SECTION I

Industrial wastes have an effect, in one way or another, on the streams that they are discharged into. When the water is affected such that it is unacceptable for drinking, swimming, fishing, or any other of its normal uses, it is considered to be polluted. According to Nemerow (6:3):

> Streams can assimilate a certain quantity of waste before reaching a polluted state. Generally speaking, the larger, swifter, and more remote streams, that are not much used by people, are able to tolerate a considerable amount of waste. Too much of any type of polluting material causes a nuisance, and thus a polluted state exists. To call a stream polluted, therefore, generally means that the stream has been supersaturated with a specific pollutant. The following materials can cause pollution:
>
> inorganic salts
> acids and/or alkalis
> organic matter
> suspended solids
> floating (lighter-than-water) solids
> heated water
> color
> toxic chemicals
> microorganisms
> radioactive materials
> foam-producing matter

*Inorganic salts* (a colorless or white substance found in nature both in minerals and in solution; also a compound derived from an acid), usually found in industrial wastes, can result in the water supply for industries, communities and agriculture being too "hard" to use.

*Acids* (compounds capable of reacting with a base to form a salt) *and/or alkalis* (substances which are typically soluable in water, sour to taste, and redden litmus), found in wastes from the chemical industry, make streams undesirable for fish, other aquatic life and for recreational purposes (boating, swimming etc.).

*Organic matter* (produced by/from animals or plants), uses up the oxygen in streams causing unpleasant tastes, odors and putrefaction. Oxygen is a prime ingredient for life. Without sufficient oxygen in the water, fish and most other aquatic life will die.

*Floating (lighter-than-water) solids* such as oils, or greases hinder the growth of plant food by blocking the passage of light through the water.

*Heated water* (water temperature higher than normal for use or for the specific environment) is caused from discharging higher temperature waste and/or water into streams. This adversely affects the oxygen level and the aquatic life in the water and the industries that use the water.

*Color* (a distinct quality of visible phenomena such as red, blue, green and yellow) is an indicator of pollution, and comes from the wastes of tanneries, slaughter houses, textile mills and other industries.

*Toxic chemicals* (poisonous substances), even in very small concentrations can have a detrimental effect on fresh water fish and other small marine life. It can also have a cumulative effect on the human digestive tract over relatively long periods of time.

*Microorganisms* (organisms of microscopic size, i.e., bacteria and protozoa) are sometimes discharged into streams in the wastes of tanneries, slaughter houses, food plants and other industries.

*Radioactive materials* (the property possessed by certain elements i.e., radium, uranium, etc. of emitting radiant energy) are generated from atomic power plants, and the manufacture of fissionable materials. They have posed some unique problems for the sanitary engineer. One of these problems is the absorption of radioactivity by water due to its biological and hydrological characteristics.

*Foam-producing matter* (waste particles which can produce a mass of very small bubbles on water surface) is usually contained in the discharged wastes from chemical plants, pulp and paper mills, and other industries. The undesirable appearance generated is usually an indicator of contamination and is often more objectionable to the public than a stream that lacks sufficient oxygen.

Reducing the volume of industrial wastes being discharged into streams should be the initial action taken to minimize the effect of these wastes. This can be done through: (1) separation of the process water from the cooling water, (2) the redesign of production operations to reduce waste, (3) waste water conservation and (4) recycling effluents into industrial raw water supply (6:12-14).

The next major action which should be undertaken by industry is the reduction of waste strength. Any attempt made by industry to reduce the total poundage of waste which has to be treated will result in money saved. A reduction in the strength of wastes may be accomplished through: (1) equipment changes, (2) waste separation, (3) process changes, (4) waste equalization, and (5) by-product recovery (6:16-21).

### SECTION II

Industries can be divided roughly into five major classifications—apparel, food processing, materials, chemicals, and energy. In this section the origin, character, and methods of treatment of the major types of waste from the last three industry classifications will be briefly described.

In order to avoid confusion, Besselievre (2:6) suggest that:

> In discussing industrial-waste handling and treatment, we must also distinguish between "disposal" and "treatment". Any manner in which an industry gets rid of its wastes, into city sewers, into the nearest stream or by hauling them away to a dump, is "disposal". "Treatment", on the other hand, is the process of altering the character or physical makeup of a waste stream to prevent pollution of water sources by contaminating components, to safeguard the public health, use, or comfort or to enable the industry to reuse the water portion of the wastes for other purposes in its own or other plants.

*Materials Industries*

The materials industries and their wastes can be subdivided into the three classifications of (1) liquid-materials, (2) metal, and (3) wood fiber. They can be differentiated from other industries in that their products cannot be eaten, are not considered chemicals, and are not normally used as wearing apparel.

*Liquid-Materials Industries Wastes*

Included are wastes generated by the glass, oil-refining, rubber, and naval store industries.

*Glass-industry wastes.* The wates generated during the manufacture of optical glass contain large quantities of glass and glass particles of microscopic size, detergents, and the fine iron particles used in the polishing process. The mixture thus formed has these characteristics: (1) alkaline reaction, (2) bright red color, (3) a low BOD, (4) nonsettleable solids, (5) resistance to acid cracking, and (6) resistance to alum coagulation. The method of treatment involves coagulation caused by the use of calcium chloride. This produces a clear supernatant when 259 ppm of $CaCl_2$ is used. In at least one case, this method resulted in a reduction of BOD from 40 to 28 ppm, total solids from 1080 to 3 ppm, and the color from 900 to 35 ppm. This coagulant was much better than any other coagulant used (6:455).

*Oil-field and refinery wastes.* These are the wastes that originate from the refining and production of oil during the pumping, desalting, distilling, fractionation, alkylation, and polymerization phases. The volume of wastes from oil refineries is large and contains both suspended and dissolved solids, large amounts of dissolved iron, acids, chlorides, cresylates, oil, phenolic compounds, and wax, as well as other pollutants. Refinery wastes can be reduced through good housekeeping, especially including (1) preventative maintenance of pipelines and equipment to reduce oil leaks, (2) the isolation and separate treatment of obnoxious wastes, (3) the prevention or treatment of oil emulsion formation, and (4) the removal of floating oil in separators. When emulsions are not present, American Petroleum Institute (API) separators can reduce the BOD by 5 to 10 ppm. The various treatments used for oil wastes include aeration, biological oxidation, centrifugation, chemical floculation, evaporation, air flotation, mixing, incineration, and scrubbing with flue gas (6:429-434).

*Rubber wastes.* In general, there are three sources of rubber waste: (1) synthetic rubber manufacturing, (2) natural rubber manufacturing, and (3) rubber reclaiming. Synthetic rubber is manufactured through the production of raw materials for polymerization (butadiene and styrene) and the actual polymerization operation. Natural rubber, produced by coagulation of latex, produces little in the way of liquid wastes except cooling water. The process of rubber reclamation involves shredding old rubber, removing iron materials and sometimes recovering the cotton fabric (6:446-448).

The wastes generated from the production of rubber are objectionable because of their high BOD, odor, and taste imparting properties. They also present a variety of problems depending on the raw materials used, where the manufacturer is located, and the variety of commodities produced. Because rubber is composed of many substances, the treatment generally practiced today for rubber wastes include aeration, biological reduction, chlorination, and sulfonation. A certain amount of success has also been gained using coagulation, ozonation, and activated carbon treatment methods (6:446-449).

*Naval-stores wastes.* The wastes that originate from the manufacture of naval stores such as dipentene, pine oil, wood, resin, and wood turpentine are the result of refining oleoresinous materials from pine wood. Although several remedial recommendations have been proposed for the handling of naval store wastes, such as elimination or stopping waste discharge, by-product recovery, equalization of flow, recirculation, and reuse, little waste treatment is practiced. Experiments have shown that an 83 percent BOD reduction can be gained using trickling filtration (6:456).

*Metal Industries*

Those industries that process or manufacture iron, steel and other metals are included in this category. The wastes from the various operations vary widely in characteristics and volume.

*Iron-foundry wastes.* The major waste from iron-foundries is the dry sand used in making molds for manufacturing castings. This waste which is generated from the production of castings made from molten metal also contains solids, core sands, and fly ash from the molding process. The used sand is flushed with water and transported to a disposal site where some method of sand reclamation is used. One waste treatment is the use of a filter to remove excess water from the sand which is then dried for reuse. Another method uses primary sedimentation prior to reuse of the water (6:427-429).

*Steel-mill wastes.* Steel mill wastes originate primarily from the purification of blast-furnace gas, by-product coke, the cooling fluids used in rolling mills, pig iron cooling, melting pots and pickling. The various wastes from the typical steel plant include gas-washer waters, scale-bearing waters, acid wastes (spent pickling solution, etc.), oil-bearing wastes, and other waste waters used in cleaning, granulating slag, and cooling (4:243).

In the treatment of by-product coke plant waste, efficient recovery and removal units should be used. The use of recycled water can reduce the BOD by one-third. Coke dust can be removed by quench water: the free oil in the benzol stills can be removed with gravity separators and recirculation of final cooling water can help reduce the amount of phenol discharged to waste. Because the treatment of pickling liquor is a major problem, it is not economically feasible for small steel plants to attempt recovery of by-products from the waste. Neutralization with lime is the treatment method

commonly used by steel mills (6:397-403).

*Metal-plating wastes.* Although these wastes do not approach the volume of wastes generated by some other industries, their extremely toxic nature makes them important sources of pollution. These polluting wastes originate during (1) the stripping process which removes undesirable metallic, metallic oxide, or other coatings on the work to be plated, (2) the cleaning process where any soil, oil and grease are removed, and (3) the plating process where the actual deposition of the metal takes place (5:283-284).

The general sources of waste from plating operations include (1) reclaimable rinses, (2) continuous overflow rinses, and (3) batch solutions. The disposal or immunization of waste from the plating operations can be achieved by modifying the manufacturing process (either its design or its operation), and the installation of a chemical treatment plant for the removal of toxic and objectionable materials from the plating room effluents (6:408-413). Substantial reduction in these wastes can often be obtained through good housekeeping.

*Other metal-plant wastes.* Besides the iron and steel industry, metal industries which process, for example, aluminum, brass, copper, and lead, also generate wastes which pollute streams. The major potentially objectionable waste waters in quantity and toxicity seem to come from the pickling operations in the brass and copper industry (5:383-384). These waters can be treated by precipitation of the metal as hydroxides in alkaline solutions, by neutralization, or by electrolysis (6:407).

### Wood Fibers Industries

Those industries responsible for the manufacturing and processing of paper and pulp are included in this section.

*Pulp and paper mill wastes.* The production of paper is divided into two phases: (1) cellulose fiber preparation in the pulp mill and (2) manufacture of the paper in the paper mill. Some of the more important raw products from which the pulp is made are bagging, bamboo, esporto, flax, hemp, rags, straw, sugar cane, textile cuttings, thread, waste paper, and wood. Each of these raw products is processed for the removal of foreign material and the release of cellulose in useable form for the manufacture of different grades of paper (3:199-209).

The wastes from pulp mills come from the various manufacturing processes, such as grinding, digesting cooking, washing, bleaching, thickening, defibering, and deinking. Paper mill waste waters contain effluents from wood preapration, screening and pulp cleaning, mechanical pulping, mechanical chemical pulping, chemical pulping, textile fiber pulping, deinking and belaching. Chemical pulping wastes, such as sulfide waste liquor, are the strongest effluents and the most difficult to dispose of from a pollution point of view (6:368-373).

The treatment of pulp and paper-mill wastes is accomplished through: (1) activated sludge, (2) chemical precipation, (3) lagooning (4) recovery methods, and (5) sedimentation and flotation (6:378).

### The Chemical Industries

Wastes from chemical manufacturing industries are extremely varied in their nature. Any given product may be made from different raw materials, using any number of processes, and produce effluents of entirely different characteristics. The wastes are generated from manufacturing processes which produce acids, bases, cornstarch, detergents, explosives, fertilizers, fungicides, insecticides, plastics, resins, and many other products. The chemical wastes are acids, bases, toxic materials, and matter low in suspended solids and high in BOD, color, and inflammability (6:461-487).

### Acid Wastes

Since most states have laws which require that the standard of receiving streams must be maintained between 6.0 and 9.0 ph, the apparel, chemical and material industries are not allowed to empty their wastes into our streams. Neutralization is considered the primary method of treatment of acid wastes. Nemerow (6:461) mentions two methods of neutralizing acid wastes: (1) by means of an up flow limestone bed which can handle wastes up to 10,000 ppm of mineral acidity in a bed with a receiving capability of 0.1 mdg. of waste and (2) the use of a Beckman ph electrode for control, using lime for automatically neutralizing acid citrus wastes.

### Cornstarch-Industry Wastes

This industry manufactures starch, oil, syrup, sugar and cattle feed from corn. A bushel of average quality corn, containing 16% moisture and weighing about 56 pounds, yields about 32 pounds of pearl starch, 1.6 pounds of oil, and 13 to 14 pounds of feed by the wet-milling process. Recovery or prevention of wastes in this industry has been an age-old problem, and many recovery systems have been developed. In the early 1930's a system called the "bottled-up" system was generally adopted for the reuse of certain waste waters in the plants. The losses of dry corn material were reduced to less than 0.5 percent (8:132-133).

The primary wastes from this industry are from the "bottled-up" process, the syrup from final wastes, and the entrainment of volatile organics in the evaporator condensate (6:469). Imhoff tanks, activated sludge, and trickling filters have all been used satisfactorily on corn product wastes mixed with sewage (5:376).

### The Explosives Industry Wastes

Waste problems from the manufacture of explosives and munitions are mostly localized in their effects. The chief forms of explosives produced are trinitrotoluene (TNT), smokeless powder, and small-arms ammunition. TNT wastes are very acidic, clear, highly colored, and high in percentage of volatile solids. They resist alteration following discharge into the receiving waters. The two major wastes from the industry are the sulfite-purification wash water and the acid waters used for the washing after nitration (6:478-486).

The waste generated from the manufacture of smokeless powder involves (1) acid residue, (2) analine, (3) ether-alcohol, and (4) guncotton. Small-arms ammunition wastes are characteristically greenish-gray in color, turbid, oily or soapy to the smell and contain copper and zinc from the acid pickling baths (6:479).

Several methods are recommended for treating explosive wastes, including (1) TNT - use of black garden soil for filtration, (2) smokeless power - use of both aeration and biological oxidation for decomposition, and (3) small-arms ammunition - use of grease flotation and chemical precipitation (6:485-486).

*The Insecticide Industry Wastes*

Although the wastes of DDT contain a great deal of acid, the wastes from the production of 2, 4 dichlorophenoxyacetic acid (2, 4-D) are probably the most troublesome of those derived from the production of chemicals by the insecticide industry. The alkaline chlorination process is the method used to treat this waste and destroys 95 to 98 percent of the dichlorophenol. The other primary method of disposal has involved dumping the wastes into sufficient dilution water such as the ocean. Because of the toxicity of the majority of the constituents in the wastes, treatment by municipality biological plants has been impractical (6:489-490).

*The Phosphate Industry Wastes*

Florida accounts for about 70 percent of the phosphate rock produced in the United States and the remainder comes from several western states. Waste water treatment from the pebble phosphate rock operations in Florida comprises one of the major problems of the industry. These waters come from mining the rock and processing it into its basic elements. Waste treatment is accomplished with modern flotators and through the extensive use of land areas for tailings, storage, and slime settling. Mechanical clarifiers for removal of sand tailings and the storage of waste water prior to reuse are also in use (6:470-473).

*The Soap and Detergent Industry Wastes*

The wastes produced by this industry generally cause much public concern when discharged from homes and factories even through relatively small volumes of waste are produced. Recovery of floatable fatty acids has proven to be profitable to the soap industry. One successful method of treating soap plant wastes is by flotation with air bubbles. The floated sludge is skimmed into a receiving tank from which it is pumped back into the factory for reprocessing. Detergents, surface-active compounds used as cleaning agents, are extremely difficult to remove at water treatment plants (6:475-478).

*Energy Industries*

The energy industries involved in the production of power include (1) steam power plants, (2) the coal industry, and (3) the nuclear industry.

*Steam Power Plant Wastes*

The two essential ingredients necessary for the production of power are water and fuel. Although the type of fuel can vary, water is required for the generation of power in any significant quantity. The water is used for cooling purposes and is then returned to its source at an elevated temperature. The problems associated with this discharge of cooling waters vary depending on the type of waterways into which they are discharged. Not including the discharged hot water, power plants must also dispose of other waste materials. These are the acids, alkaline chemical solutions, caustic solutions, fly ash, greases and other miscellaneous solid and liquid wastes generated from cleaning and other normal operations within the power plant (3:491-492).

Other than fly ash, there is little evidence of any treatment of power plant wastes. In the disposal of fly ash, the ash is first separated from the exhaust gasses, water is added and the slurry is pumped to settling basins. After the ash settles, the water is discharged into a stream or other water disposal area (6:493).

*The Coal Industry Wastes*

The primary wastes from the coal industry are (1) acid drainage from coal mines and (2) effluents from the washeries that clean and process the coal. Acid drainage wastes are the result of mine water picking up various minerals exposed to the oxidizing action of air, water, and bacteria. Coal washer wastes originate during the cleaning operation where fine coal particles become suspended in the wash water (6:496-500).

The following control measures are recommended for the treatment of acid drainage wastes: (1) drainage control of water, (2) elimination of the slug effects of pumping, (3) control of the sulfuric refuse to insure that it does not come in contact with water, (4) sealing of abandoned mines to prevent water from entering the sulfur-bearing soil, and (5) protection of water quality through treatment of mine drainage (6:501).

There are two methods of treating coal washer wastes: (1) adoption of more efficient methods of cleaning ultrafine coal and (2) installation of settling tanks for the collection of the coal silt in the waste water (6:500).

*Nuclear Energy (Radioactive Wastes)*

Radioactive wastes are similar to chemical wastes in that the methods of removal are the same as those used in the treatment of chemical wastes; however, they are unique in comparison with other industrial wastes in that radioactivity is not detectable by human senses, the toxicity is greater, and there is no known process for destroying radioactivity (5:431-433).

There are several sources of radioactive wastes: (1) fuel-element processing, (2) laundering of contaminated clothes, (3) cooling waters from nuclear power plants, (4) uranium ore processing, and (5) hospital and research laboratory wastes. The radioactive wastes may be liquid, gaseous, or solid and are treated or disposed of in the following manner: (a) liquid wastes are disposed of either through concentration, storage and burial, or through dilution and discharge into sewer or stream systems, (b) the radioactive atmospheric contaminants of gaseous waste can be categorized as either gaseous or particulate matter and can be controlled at the source by the application of local exhaust ventilation, (c) solid wastes may be disposed of by burial, by incineration if combustible, or by remelting if metallic (6:525-536).

## CONCLUSION

There are many types of waste generated by industry from numerous production processes. These wastes result in the pollution of our streams, rendering them unfit for domestic, commercial, or recreational purposes. Therefore, the design of the production process has an important effect on the quantity of waste water generated as well as the characteristics of the waste water itself. New production techniques, in many cases, have resulted in the use of less water through the increased reuse of water and recovery of raw materials. This decreases the quantity and sometimes the quality of the wastes to be treated.

In order for an industrial waste treatment program to be effective, the industrial, chemical and/or sanitary engineer must examine the specific industrial process to determine if the equipment and raw materials have been efficiently used. Then he should study the quantity, characteristics, and polluting strength of the waste, the capacity of the stream to assimilate the waste, and the cost of which ever process is selected. Then he should take action.

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# CHAPTER IV — SOLID WASTES

## INDUSTRIAL, COMMERCIAL, RESIDENTIAL

By William G. Berry, Jr., Capt, USAF

*Solid Waste Characteristics*

Inseparable from the topics of energy and resource use, pollution, and the environment is the topic of solid wastes. This chapter focuses on the generation and effects of solid wastes and how solid wastes relates to the above topics. Specific areas addressed are: what a solid waste is; where it comes from; what we do with it; and the effects of solid waste. The succeeding chapter will cover the collection and disposal problems of solid wastes.

*What is a Solid Waste*

According to Emil T. Chanlett in his book *Environmental Protection*, a solid waste is any refuse not capable of being fluid borne (2:278). He defines refuse as anything considered waste by the owner and then "refused" by him. A further definition by the U.S. Department of Health, Education and Welfare is that solid wastes are those wastes of the community (excluding body wastes) (6:44). For simplicity then, one might think of solid wastes as refuse which is non-flushable into sanitary/storm sewage systems because of some nature of the refuse (e.g., acids, lumber, newspaper, etc.). This brings us to the reality that almost anything and everything at one time or another winds up as solid wastes. A good case in point is man: good old "ashes to ashes and dust to dust" himself. It should become apparent to the reader that there is no avoiding solid wastes. Accordingly, I ask the reader to keep in mind these facts: the generation of solid wastes is here to stay; the amount of solid wastes per capita is increasing and the problems of the effects of solid wastes, although historically ignored, are becoming more and more important and unavoidable. On this note we now turn to the types and sources of solid wastes.

*Types and Sources of Solid Wastes*

Chanlett classifies solid wastes into the following types:

- Garbage (any putrescible food refuse);
- debris (from construction, demolition, etc.);
- Litter;
- Oversized Discards (e.g., thrown away stoves, abandoned autos, etc.);
- Dead Animals (including man);
- Waste Water Treatment Plants Refuse;
- Industrial Refuse (including animal manure);
- Mineral Extraction and Processing Wastes; and
- Rubbish (any other refuse other than the above) (2:278-282).

The above types of solid wastes are usually grouped under broader source categories such as residential, commercial, industrial, municipal, etc. For example, in a 1973 report by the Research and Education Association, the above types of solid wastes are grouped into the source categories of residential, commercial, and industrial. Which types are in which source category is relatively unimportant. What is important is the following solid waste in pounds per capita per day generated in the United States:

| | #/Capita/Day |
|---|---|
| Residential | 2.4 |
| Commercial | 1.0 |
| Bulky | .3 |
| Industrial | 3.2 |
| | 6.9 |

Only 1.8 #/capita/day of this is disposed of by industry; the remaining 5.1 #/capita/day has to be disposed of by private/municipal sites (4:430) Thus, even though the reader might think he is only generating the relatively small 2.4 #/capita/day, his representative fair share of *all* the solid waste generated as a result of processing his food, the making of his clothes, goods, etc., is the considerably greater 6.9 #/capita/day.

The Research and Education Association further divides municipal solid wastes into the following components and includes average percentages of each:

| *Component* | *% of all Refuse (By Weight)* |
|---|---|
| Rubbish | |
| Paper | 42.0 |
| Wood | 2.4 |
| Brass | 4.0 |
| Brush | 1.5 |
| Greenry | 1.5 |
| Leaves | 5.0 |
| Leather | 0.3 |
| Rubber | 0.6 |
| Plastics | 0.7 |
| Oils, Paints | 0.8 |
| Linoleum | 0.1 |
| Rags | 0.6 |
| Street Sweepings | 3.0 |
| Dirt | 1.0 |
| Miscellaneous other | 0.5 |
| Food Wastes | 12.0 |
| Non-Combustibles | |
| Metals | 8.0 |
| Glass and Ceramics | 6.0 |
| Ashes | 10.0 |
| | 100.0 |

The above #/capita/day and percentages vary slightly from report to report due to different classification schemes and sampling plans used. The reader should note however certain relationships such as the significant percentage (about 50%) of paper solid wastes. Also municipal solid wastes are only a portion of all the solid wastes generated. A report depicts the relative sizes of solid wastes generated (in tons per year) by the different sources (2:282). A 1968 U.S. Public Health Service Report:

| | *Millions of Tons/Year* |
|---|---|
| Household, commercial, and municipal | 250 |
| Industrial | 110 |
| Agricultural and Crop Residues | 550 |
| Animal manure | 2,000 |
| Mining and refining | 1,000 |
| Total | 4,010 |

Some items of solid wastes worth mentioning specifically are: Paper, once again, which accounts for almost half of municipal solid wastes; Aluminum cans and glass containers, one use of which has increased significantly in the last decade (Although non-degradable, the emphasis should be on increased use of them because they *are* recycleable and textiles. These are discussed by Thomas D. Clark in his report "Economic Realities of Reclaiming Natural Resources in Solid Wastes (3). Other items probably familiar to the reader are abandoned autos, tires, car mufflers, etc. In other words, solid wastes are all around us. Now that we have seen what solid wastes are and where they come from, what do we do with solid waste?

### *The Effects of Solid Wastes*

As previously mentioned, solid wastes, energy conservation, and pollution are topics that are highly related. You cannot fully understand one without knowing the effects on the other. To mention a few, solid wastes have effects on/of: health, esthetics, costs, and resource conservation.

### *Health Effects*

Obviously, anytime man uses an open dump to get rid of his solid wastes, he runs the risk of providing insect breeding grounds, rodent feeding grounds, and water pollution. Even with sanitary land fills, methane, $CO_2$, and ammonia nitrogen, are produced (2:299). If man chooses to incinerate, he runs the risk of air pollution with all of its harmful effects. If he dumps at sea, he can pollute the water. If he sorts for recycling he runs the risks of cuts and infections. We also have the health problem involved with radioactive wastes, chemical wastes, etc. In short, solid wastes have a health effect everywhere we look. What is interesting to note however, is that most authors consider the harmful health effects of solid wastes as relatively small in comparison to the harmful health effects caused by air pollution, water pollution, etc. At any rate, the health effects of solid wastes are real and cannot be ignored.

### *Esthetic and Ecological Effects*

The most obvious esthetic effects of solid wastes are those that have to do with sight and smell. A good example is that of an open dump which is an eyesore and certainly unpleasant to smell. Another eyesore example is that of littering. Other "small" examples are the odors around processing plants, feed lots, etc.

An important factor in the esthetic effect of solid waste is public acceptance of the problem. For example, if the public is made aware of the problems associated with and the benefit to be gained from using a sanitary landfill, the annoyance is reduced. Although hard to quantify, esthetic effects are undoubtedly important. A good, although long-term, benefit to be gained from the above sanitary landfill could be the eventual use of it as a park or recreational area.

In general, solid wastes can have a good or bad esthetic effect depending on good or bad solid waste management. Along with this statement is the fact that the environment has to be able to assimilate the solid wastes. For example, it is becoming more and more obvious that the oceans will not be able to assimilate all of our solid wastes on a long term basis. At the present, we have to resort to using sanitary landfill until we can devise a method to efficiently and effectively reuse and recycle our solid wastes.

### *Costs Effects*

Herein lies the real solid wastes problem—costs. It costs money to both collect and dispose of solid wastes. Land for sanitary landfills is becoming not only more scarce, but also more expensive. Inflation and increased quantities result in higher collection and transportation costs of solid wastes. To recycle costs money; to reuse costs money. For example, solid wastes *can* be incinerated to create heat and pryolysis can be used to produce oil, but with our present technology, the costs for the initial capital outlay for operation and maintenance are so high as to be nearly prohibitive. According to one report, it costs approximately $5.39 per capita per year for collection of solid wastes and $1.42 per capita per year for disposal of solid wastes (5:21). These figures of course vary not only from report to report and from year to year, but also with location, disposal method, etc. Interesting to note is the fact that the community costs of collection and disposal of solid wastes are second only to the costs of education in most communities in this country (2:283). These costs, in addition, are bound to increase not only because of inflation and population growth, but also because total refuse and the per capita refuse production will increase over time (4:483). This is illustrated in Figure 1 and 2.

### *Resource Conservation Effects*

Along with the above mentioned population growth and the increased per capita production of solid wastes is the increased per capita use of natural resources. This is due to the improved standard of living and the growing affluence of our society. The point to be remembered is that not only will we be using more resources, we will be wasting more. Unless we find an efficient effective way to reuse/recycle our resources, we will accelerate this useage and eventually completely deplete all of the worlds natural resources. According to Adler, the U.S. who has only 7% of the world's population but presently uses half of the world's non-renewable resources (1:287). Some of the important solid waste problems that will need addressing in the near future might include: energy and resource conservation; resource recovery through efficient and effective means of reuse and recycling.

### *Future Trends*

As should be evident by now, things in the solid waste field aren't going to get better in the immediate future. The population is growing (although the growth does appear to be slowing down). The per capita use and waste of resources will increase. Immediate relief through reuse and recycling is not on the economic horizon. Costs are increasing; land availability for sanitary landfills is decreasing. It is evident then that we need to improve our technology, plus stress public awareness of the above problems.

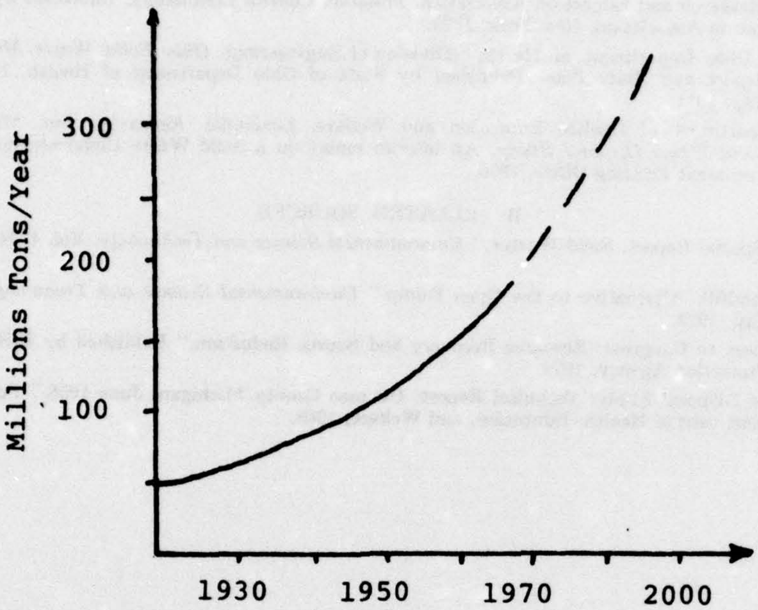


**Figure 1. Total Refuse Production in the U.S.**

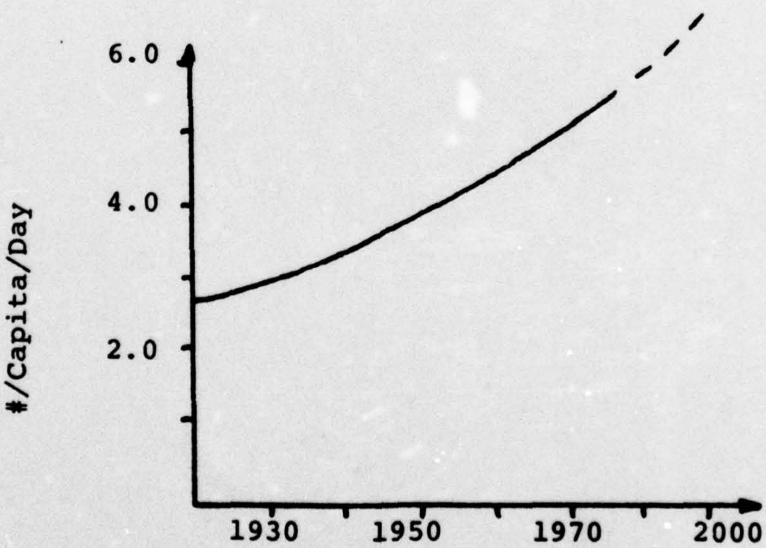


**Figure 2. Per Capita Refuse Production.**

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# CHAPTER IV — SOLID WASTES

## SOLID WASTE COLLECTION AND DISPOSAL

By Walter H. Elbinger

### *On-Site Gathering Methods*

On-site gathering usually occurs where people live or work and is usually the first link of the waste collection chain which finally results in disposal. At home, the most popular method is the can under the sink and wastepaper baskets throughout the house. From here, the refuse usually ends up in the garbage can or plastic trash bag to be picked up at a later date. In the office, a similar procedure is usually followed.

A familiar method of solid waste treatment in the home is the garbage grinder in the kitchen sink which is normally fed all the vegetable type waste that the household generates each day. This type of treatment is really a water slurry transportation medium which can create problems at the waste water treatment plant if the facilities are not adequately prepared for this type of waste. In most areas, this is not a present day problem.

Within industry and even some housing developments, the refuse that is generated is collected by the janitorial service and then placed in containers suitable for temporary refuse, storage and eventual pick up.

Gravity chutes have been used in multi-story buildings to reduce the occupants' time and effort devoted to solid waste handling and in order to reduce pick-up costs. However, bulk items and highly flammable items do not lend themselves to this type of operation and must be handled by other methods. If properly installed, gravity chutes have proven satisfactory from a fire hazard as well as health viewpoint and are more acceptable and efficient than service elevators (4:16-14).

Pneumatic pipelines are basically a closed vacuum system driven by a vacuum pump at one end. This type of arrangement has been used successfully in machine and carpentry shop to collect metal and wood chips as well as dust. The advantage to pneumatic pipelines over a gravity chute is that wastes can be moved both horizontally and vertically. Installation and health hazards are the same as those with gravity chutes and this method is more expensive due to the equipment, power, and maintenance requirements (4:17-18).

The hydraulic pipeline is readily identified if we call it a sewer and remember the garbage grinder in the kitchen. Flow is mostly by gravity although pipelines can be operated under pressure. Almost any solid waste can be transported if the waste is properly treated, the pipeline is properly constructed, and adequate pressure is applied which may be in addition to gravity. Health hazards must be considered as well as the waste handling equipment at the end of the pipeline (4:19-20).

Conveyor systems come in various configurations: flat, belt, bucket, apron, flight, dumpers, and hinged steel. Conveyors are usually used to transport waste a short distance and are subject to jamming due to their being almost totally open. Conveyor systems are usually expensive to purchase and maintain and are used where great quantities of material of uniform size must be moved rapidly. Mining operations can be cited as a good example (4:20-21).

Vacuum methods are used for on-site gathering of waste. The most popular to most people would of course be the vacuum cleaner in the home. Vacuum systems are efficient for gathering dust, dirt, leaves, litter, and loose objects and in most areas are preferable to sweeping especially in shop areas (4:21).

Hydraulic washdown is nothing more than flushing with a liquid. Cleaning a city street is a good example although freezing weather is a consideration (4:22). In a hydraulic washdown, consideration should be given to the solid waste being disposed and its impact on the collection system. It may be easier and cheaper to use another method such as sweeping or a vacuum pick-up.

### *Storage Methods*

Normally little thought is given to solid waste storage because it is usually removed from the area within a reasonable length of time and does not cause health problems or is not unsightly. When improperly handled, trash is wind blown or the dogs turn over the garbage can; then the citizen gets concerned. With solid waste, it can be considered out of sight, out of mind. Storage methods are usually of short duration and pick-up is usually once or twice per week depending on the type of waste and the amount of waste generated.

The container probably most popular to the homeowner is the garbage can sitting behind the house or in the alley. These cans should be easily cleaned and have tight covers to prevent flies and stray dogs from getting to the contents.

Paper bags are used for storage with some having special treatment such as a plastic wax or coating. Paper bags are relatively expensive and tear easily and also do not keep waste odors from escaping (4:30).

Plastic bags which are seen advertised in various sizes and weights are more tear resistance than paper and are also more puncture proof. Plastic bags are used for liners of other containers as well as being used by themselves. Once filled, a twist-type wire seal prevents odors from escaping or spillage. Plastic bags keep containers clean, when used as a liner, and apperance of the storage area is a plus factor. Of course the cost of the plastic bag is the principal disadvantage especially if the bag is not used again (4:31-32).

When large quantities of waste or specialized wastes are generated then mechanical loaded containers are used. The dumpsters seen at shopping centers are an example and can be of the self-loading type container with front, rear, or side loading for use with compactor trucks or lugger box for use with hoist trucks or roll-off containers with tilt frame collection vehicles (4:33).

### *Collection Methods*

Wastes must be collected and removed from the point where it is generated so that it will not create nuisances and health hazards. A wide variety of motor vehicle and container configurations are used for the collection of this waste. These vehicles, of one sort or another, pick

up the waste from the container provided or pick up the container. The vehicle may compact the waste, i.e., reduce the volume so that the container vehicle may haul more waste which reduces the cost by reducing the number of trips to be made.

Open-top vehicles are not used today as much as they have in the past due to the height of the stake bed or dump truck sides being as much as 10 feet for the loading height. The open top is also highly susceptible to having litter blown from the open vehicle (4:50). For demolition wastes or where construction requires bulky waste, open-top vehicles may still be the best method of removing the waste. An improvement over the open-top vehicle would be an enclosed vehicle, but these have low volume and density and are not very economical.

Compactor vehicles come in various configurations and may be rear, front, or side loaded. All work on basically the same principle which used a hydraulically operated mechanical ram which compresses the waste and hence reduces the volume allowing the vehicle to haul more of the densified waste. Compactor vehicles are useful in collecting the neighborhood type solid waste but do not lend themselves to pick-up of bulky debris, appliances, or scrap metal (4:52). Compactor vehicles have advantages in that they are easily and rapidly loaded and easily unloaded and can be procured to meet the legal payload in the area where utilized.

Rasp type vehicles contain basically a rotating drum with a helical screw on the inside which first reduces the size by crushing and tearing the waste which is then compressed. This type of vehicle has not been widely accepted in this country because of the high loading height as well as this type of operation having a tendency to throw waste from the vehicle during the crushing process (4:62).

Satellite systems are used where numerous sources generate small amounts of waste. Storage containers may be centrally located for the waste deposit; scooter type vehicles may be used in the satellite operation or detachable body compactor systems may be used. Regardless of operation the noise level associated with waste collection may be of major consideration in housing areas or highly concentrated industrial areas (4:63).

Container haul is of the type where the container and its waste contents are removed from the pick-up site and hauled to the disposal area. Lugger boxes are special containers designed for this purpose and must fit the vehicle's hoist and hydraulic system. Lugger boxes are well suited where there is a short haul with lots of waste as well as special waste types. Containers of this type are not well suited for storage (4:68).

Tilt frame vehicles are used where large quantities of waste from a single source is generated. This type of vehicle operates on the same principle as container haul described above but dumping is achieved by tilting the frame with the container secured and opening the rear door of the container (4:72).

*Transfer Methods*

Usually solid wastes are hauled to the processing facility or disposal site in the containers and vehicles in which they are collected. A transfer system, where the solid waste is collected and placed in larger vehicles or aboard a train, is economical when this method costs less than direct haul by the collection vehicles. The transfer station should be as near to the collection area as possible. Balers or other methods of volume reduction are desirable at the transfer station so that the maximum use of the subsequent transportation method may be utilized. The transfer station may also be the ideal place to establish the separation of materials for reclamation (4:80).

*Processing Methods*

The method that is probably the oldest and also that which is disappearing most rapidly is what has in the past been called a "dump." This dump may have been nothing more than a low spot or ravine where the solid wastes were deposited without regard to health hazards or rodents.

Today's methods can be simple or complex. Processing may be accomplished by one or more of the following methods or in combination of these methods: densification, reduction in size, reduction in volume, separation, and resource recovery or waste utilization (4:88).

Densification is used to reduce the volume of the solid waste which gives improved utilization of the storage capacity in containers, transportation systems, as well as better utilization of landfills. Densification falls into three main categories which are: stationary compactors, single stroke, and multistage balers (4:88).

The compactor that is becoming popular today is that in the kitchen which according to the advertisements can compress several garbage cans full of household waste into a small bag which is easily and conveniently carried from the residence. All compactors function on basically the same cycle which is feeding the hopper with the waste material, then to the compacting area where it is compressed by a compacting ram. Compactors are available which range from 20 to 720 cubic yards per hour when operated continuously. Volume may be reduced from four to ten times its original volume depending upon the solid waste and the compactor (4:90).

Balers may be obtained in single and multistroke as well as vertical and horizontal configuration. The solid wastes are placed in a compression chamber, compressed and bound together with metal straps, wire, or twine. In small compactors the bales may be enclosed in a plastic or cardboard box. Continuous baling is possible with a horizontal baler but not a vertical baler. Multistage balers are generally batch fed with the density of the bales being 55 to 65 lbs. per cubic foot compared to 20 to 55 lbs. per cubic foot for single stage balers. Baling is popular in the scrap metal industry with compaction ratios of 20:1 being realized when material with the characteristics of household appliances are being baled (4:98).

Size reduction is the mechanical reduction of the solid waste so that smaller pieces are produced. Size reduction is used to give better handling properties. This uniformity of size may be important in some transportation methods, is beneficial in resource recovery methods, and has been used on land disposal. Size reduction may be accomplished by crushers, shears, shredders, clippers, rasp mills, drum pulverizers, wet pulpers, and hammermills (4:100). The names of these units describe the action by which the reduction is accomplished. These units can be obtained from various manufacturers to suit the intended use. Quite popular

for a short period of time, due to the Watergate trials, were small shredders used to render classified papers useless by reducing their volume by shredding.

Volume reduction processes do two things. The volume and the weight of the solid wastes are reduced so that the quantity of solid wastes that must finally be disposed is reduced. Volume reduction falls into combustion, composting, pyrolysis, salvaging, and recycling. Combustion for volume reduction is one of the oldest methods of processing solid wastes.

Open burning is the combustion of solid wastes in the open atmosphere and there is virtually no special equipment required. Also capital expenditures are at a minimum making open burning a rather inexpensive waste disposal method which reduces the volume of solid waste from 60 to 75 percent. A great portion of the waste is incompletely combusted and this results in smoke and offensive odors. Open combustion is no longer an acceptable technique although it is still an excellent method for the disposal of dangerous chemicals, unused ordnance, and in land clearing such as trees and brush (4:104).

A controlled combustion process for burning solid wastes is incineration which will convert the wastes to gases and residue. The semi-enclosed or enclosed incineration process is regulated so that the best combustion efficiency may be realized. Gaseous products, particulates, and some ash may be discharged into the air and may fall on the surrounding landscape unless environmental protection devices are employed to reduce the emissions to the air. The precentage of reduction may be up to 95 to 100 percent depending on the solid wastes being incinerated.

The major function of incineration is to achieve maximum combustion by evaporating the moisture of the waste, both externally and internally. In the first phase the solids are dried and ignited which results in chemical as well as physical changes. The second phase is when the gasses and particulates generated in the first phase are oxidized which requires high temperature and adequate amounts of air. Incinerators will accept most common type solid wastes such as paper products, wood, plastics, textiles, food wastes, and other household wastes. Bulky wastes are not normally acceptable due to their size as well as long burning times. Highly flammable explosive and toxic materials are acceptable if incinerated in small quantites. Large quantities of these materials along with surgical wastes and test specimens should mot be taken to a central incinerator but could be incinerated at the site of origin (4:105).

Advantages of incineration are a savings of land required because final disposal of ashes and/or residues and the incinerator itself requires relatively little land. Also, when functioning properly the incinerator is nuisance free and climatic conditions do not directly affect operation. Some disadvantages are initial substantial capital investment for the incinerator, operating costs are usually high, incineration is not a complete disposal method, the resource value of the solid waste may be partially destroyed, and air pollution may be a problem (4:106).

Incinerators may be small on-site package type with a capacity of 200 to 1400 lbs. per hour or central municipal-type incinerators which can process more than 1500 tons per day (4:107). A primary consideration today is air pollution control and the incinerators must meet the air pollution standards and are subject to test by the Environmental Protection Agency (EPA). EPA approved incinerators use auxiliary fuel—gas, oil, or electricity—to burn off gasses. Incinerators may be of special design to meet special needs and examples would include open pit, rotary kiln, vortex and fluidized bed incinerators (4:113).

*Separation*

In most resource recovery systems, the separation of solid wastes is required. Until recently there has been little activity or interest in this type of operation due to the abundance of natural resources. economic factors, and environmental considerations were overlooked.

Probably the oldest method of sorting is by hand which has been used for separation of cardboard and paper, rags, non-ferrous metals, and glass. This type of sorting lends itself to a central location and a conveyor belt systems where the sorters would stand on each side of the belt. Picking would depend upon belt speed and the type of solid waste being processed. Hand picking is usually not satisfactory for large scale operations due to high labor costs, separation is not very great and human error can cause excessive contamination of the separated wastes (4:122).

The easiest material to separate is that which contains ferrous materials such as iron and steel. This separation is accomplished by magnetic separators which can accomplish separation from ash or processed compost (4:122). Separation may be accomplished at any stage depending on economic considerations. This could be processing waste that has been shredded or equipment designed especially for large industrial operations such as scrap yards or ore processing plants.

Non-ferrous metals such as copper, brass, aluminum, and zinc could be removed by eddy-current methods. In this method, electrical current is passed through the material creating a magnetic flux. By varying the electrical current, the magnetic flux can be changed and the electromotive force generated in the plane is changing. This change creates eddy-currents in the materials which can be used for separation methods. In this method the feed material must be carefully processed to achieve the desired results (4:122).

Screening of solid waste materials may be wet or dry although dry screening is preferred for solid waste. Screening equipment is widely available and is used mainly for mineral separation. Proper selection must be made for waste separation and particle size distribution, moisture content, shape and particle size distribution of the solid waste must be considered (4:123).

There are other methods of separation; some have been used on solid wastes and some have not. Methods which shall not be discussed are spiral classifiers, flotation, dense media separation, stoners, Wilfley tables, mineral jigs, Osborne dry separator, fluid bed separator, optical sorting, inertial separation, and vortex multi-output classifier (4:123-127). Most of these methods have been developed for other than solid waste processing and their future in solid waste processing depends upon application, development, and economics.

*Resource Recovery Methods*

Resource recovery systems are usually heat recovery, material recovery, composting, and chemical conversion. Systems that process under 2,000 tons per day are not self-supporting and require various degrees of subsidy. Costs of systems that process approximately 5,000 tons

per day were comparable to sanitary landfill costs. Based on economics alone solid waste disposal by conventional methods is justified. The EPA identified recovery of materials, energy recovery, and composting as the areas most likely to yield satisfactory results :128).

Since mixed solid wastes are composed of ap-·oximately 80 percent combustible wastes, it would ›pear that these wastes would be excellent prospects ·r heat recovery which could be used for steam and ›wer production. Heat recovery systems in this country nploy a conventional refractory incinerator furnace hich is used in conjunction with a waste-heat boiler. /idely used in Germany and Europe are water cooled ırnace walls which have the advantage of increased eat transfer which also allows the furnace temperature o be controlled within desired limits. Due to the noisture content of the solid waste, an auxiliary fuel ource is usually supplied to compensate for the ·ariation in the solid waste and to assure a steady ›roduction of steam. In St. Louis, a 125 megawatt coal ›oiler has been modified to accept 400 tons per day of ıhredded solid waste as a supplemental fuel and is :apable of supplying up to 20 percent of the total heat oad of the boiler (4:136). An advertisement in a recent ssue of the *Wall Street Journal* revealed that action has een initiated to process all of the solid waste in St. Louis in the above stated manner.

Solid wastes, in addition to the above, have other resource value in that materials can be recovered which conserves resources and reduces the quantity of solid wastes that must be eventually disposed. Various methods are used for reclaiming materials each of which employ different methods of size reduction and separation, all of which must economically compete with the price of virgin material. Material recovery is usually in the area of paper, rags, plastics, rubber, and metals (4:138).

Paper is recycled to a degree. Approximately 10 million tons of paper stock representing about 21 percent of the fiber used in paper product manufacture was reclaimed in 1966. About 70 percent of reclaimed paper is bulk grade; corrugated paper and newsprint. A problem in the reuse of paper is in the contaminants they contain such as printing ink and most separation methods produce low value bulk grade paperstock. Separation of paper at the origin appears to be the best method of separation which would insure paperstock quality and give an increased value. Markets do not always exist for recycled paper and an outlet should be developed before a reclamation program is developed (4:138).

Scrap metal should be separated at the point of origin to insure the maximum market price is received. This method would give the maximum purity which is of major concern when remelted. Different grades of scrap metal have different values partially based on the degree of contamination. Problems arise in the mixed waste where the waste may be soldered, tinned, have aluminum sides or ends, and may be painted. Nonferrous metal extraction is more costly based on the increased cost of processing. In 1967, 22 percent of the total output in the aluminum industry was scrap and 80 percent of the copper production was from recycled copper (4:140).

Plastics constitute about 1 percent of the typical solid waste and this is expected to increase to slightly over 3 percent by 1976 which will probably be due to packing materials. Thermoplastics and thermosetting plastics are the two types usually encountered. Thermosetting plastics cannot be reworked while thermoplastics can be reground and remelted and hence reused. Recovery of plastics is a complicated procedure since a high quality of scrap is required and at present is not too promising since it cannot economically compete with virgin material (4:142).

Between 0.5 and 1.5 percent of solid waste is rubber. Tires, the major source of recoverable rubber, are generally readily reclaimable and easily segregated. In 1962, 360,000 tons of rubber from tires was used to produce new rubber. This represented 16 percent of the rubber usage in the United States. Two problems that rubber recovery does not have which exists in other solid wastes are practical methods for recovery and scrap quality is not a constraint (4:143).

Glass is relatively common in solid waste and comprises about 3.5 to 12.7 percent by weight. Cullet, as scrap glass is called, must be color sorted and be clean of residue and metal to command the highest market price. Color sorting and metal removal is accomplished by manual means (4:143).

The incinerator ash and noncombustible materials also have value. Metals can be recovered for reuse if the metals are not affected by the incinerator temperature. The ash can be a useful ingredient in some brick and concrete mixes (4:143).

The biochemical degradation of organic materials into a humus-like substance is called composting and over 30 different techniques have been developed to produce compost from the organic portion of the solid wastes. Composting processing is comprised of preparation, digestion, curing, finishing, and finally storing.

Preparation involves the removal of inorganic wastes, the materials are then shredded or ground, and the moisture content is adjusted to 45 to 65 percent by the addition of water or sewage sludge. The objective of digestion is to encourage the growth of microorganisms that will decompose the organic materials. The wastes are constantly or periodically agitated for air to waste contact. Digestion produces temperatures of 140° to 160°F which kills weed seeds, fly ova, and pathogenic organisms. Airing may last from 7 days to 4 months depending upon desired use. It should be noted that contrary to common belief compost has no fertilizer value. Final finishing may be regrinding or removal of unwanted materials such as glass or plastics. Storage is required since the use of compost is seasonal.

Compost has not been marketable in quantities to make it economically feasible. Cost of processing has exceeded the return desired and most plants which have been involved in composting have been closed (4:146). Although large quantities of compost may not be marketable, the nuisance free disposal of residues may be attractive from the environmental point of view.

Destructive distillation which converts solid wastes into usable by-products is called pyrolysis. At elevated temperatures in a controlled environment of zero to low oxygen, the wastes have a chemical breakdown which results in the production of solids, liquids, and gasses. Gasses contain carbon dioxide, water vapor, and a mixture of combustible hydrocarbons. The liquids contain water, acetic acid, methanol, acetone, tar, and other organic liquids. The solid is a carbon rich residue of high ash content. Proponents of pyrolysis claim ad-

vantages of controlled air pollution, salable products, reduction and sterilization of solid wastes, and the generation of energy which may be used in pyrolysis operation (4:148). The products realized from pyrolysis must compete in the market place and may or may not be competitive.

Resource recovery methods which will not be addressed in this paper are chemical conversion, hydrolysis-fermentation, oxidation, extraction, absorption, anaerobic digestion, wet oxidation, biological fractionation, and melting. Some of these methods have been used in other industries, but have not yet been economically developed for solid waste processing.

*Transportation Methods*

The collection vehicle most frequently provides the method used to transport the solid waste to the disposal site or processing center from the source or sources where it is collected. Large volume transfer trailers are usually used when an auxiliary transportation is required. To obtain efficiency the solid waste is usually compacted as previously discussed. Transfer trailers may be of the open box design and the waste is placed into the trailer by fixed equipment and are emptied by gravity or pull-off methods. Enclosed transfer trailers are usually equipped with hydraulic push-out unloading mechanisms. Another type trailer is the self-contained compactor unit where the ram of the compactor is used to discharge the waste from the rear doors (4:160).

Where large quantities of solid waste are generated which must be transported large distances to the disposal site, rail transportation should be considered. Presently there is no utilization of this method although it is being considered in some areas (4:165). Previous methods of size and volume reduction should be utilized so that the flat car or gondola may have the maximum loading.

Pipeline transportation methods for solid waste on a large scale are not being utilized although research is being made in this area. Solid food waste from the kitchen garbage grinder comes the closest to this method in present day application. Sewer transport of kitchen wastes removes it from waste storage containers which may breed flies, generate odors, and attract rats (4:167).

Where ocean disposal of solid wastes is practiced, barges or other vessels designed for the purpose may be used. This method may be the most economical where a collection area may be near a waterway (4:168).

*Final Disposal Methods*

The final disposition, after the solid waste has been collected and processed, must either be on land or at sea. Disposal methods have become more sophisticated and systemized to safeguard the public health, the environment, and to safeguard the land and the sea.

Open dumping, where solid wastes are delivered to the site and dumped on the open ground or in pits, is no longer acceptable although it was once the traditional method used. The solid waste was usually not covered and attracted rodents, scavengers, caused fires and odors, was susceptible to blowing litter, and contributed to water pollution (4:175).

A sanitary landfill is not a dump as described above. The American Society of Civil Engineers has provided the following definition for a sanitary landfill:

> Sanitary landfill is a method of disposing of refuse on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary.

Wastes are generally deposited on the ground or in trenches, then spread and compacted in layers by heavy earthmoving equipment. The solid waste is normally covered with six inches of earth after each day's operation and finally covered with two feet of earth to complete the site which prevents exposure due to weathering and provides media for the growth of vegetation. The final site should be properly graded to allow surface water to drain (4:176).

Advantages to sanitary landfills are that capital expenditures and operating costs are the lowest of all disposal methods, peak deliveries of solid wastes can be accommodated, flexibility in the landfill with little additional equipment or manpower, submarginal land may be used and reclaimed, the combined disposal of various wastes may be more economical, operations may be easily terminated without great financial loss, bulky materials may be accommodated, and a sanitary landfill may be used immediately when the land and equipment is available. Disadvantages to sanitary landfills are large amounts of land are required, operating standards are strict, the completed landfill must settle and may require periodic maintenance such as drainage, and finally the land use is restricted to special construction due to settlement and methane gas (4:177-178).

In some areas of Europe, solid wastes are shredded and then placed directly on the ground, often without cover. An EPA supported project of this type of disposal has been underway at Madison, Wisconsin with municipal wastes since 1966. Preliminary results reveal a substantial increase in the quality of landfill operations and there was a reduction in odors, wind carried litter, and there were fewer voids in the landfill which reduced landfill cover requirements.

Baling of municipal wastes has been investigated in San Diego, Chicago, and Minneapolis. Landfill volume can be reduced by 9 to 23 percent if the bales have a density of between 1600 to 1900 lbs. per cubic yard with further compaction at the disposal site being eliminated. Blowing litter is almost nonexistent and the baled solid waste does not attract rodents or birds (4:180).

Land disposal of incineration/pyrolysis, underground incineration, and composting disposal will not be discussed since these methods have found very little use.

Significant quantities of solid and semi-solid wastes are presently being disposed of in the marine environment. In 1968 it has been estimated that 62 million tons of liquid and solid wastes were disposed of in the Atlantic and Pacific Oceans. Present methods entail transporting the waste by some means and then depositing the waste in the approved location offshore. Discharge sites are selected based upon marine characteristics such as depth, aquatic life, current direction, and distance from shore. The Corps of Engineers presently issues the ocean disposal permits but it is anticipated that this function will eventually be

the responsibility of the EPA. An advantage to ocean disposal is that land is not required, but it has not yet been determined what the effects on the marine environment are, the effect of ecological balance, and the effect on man (4:182-184).

Hazardous solid wastes present special problems and must provide for protection of local ground and surface waters, the land, the air, and man. Some methods that are used are mixing with soil, evaporation, infiltration, deep well injection, and sanitary landfills. Burning may also be used. Radioactive waste falls under the cognizance of the Atomic Energy Commission.

*Management by Simulation*

Since collection methods usually have costs ranging from four to five times disposal costs, it would appear that this area would show the greatest promise in cost reduction. Mathematical models and simulation methods have been developed to investigate cost reduction for three location models: transfer facilities, disposal sites, and garbage facilities. Models have also been developed to investigate vehicle scheduling, selection, and routing. Virtually no data exists on the feasibility of using computer models or any results derived from simulation techniques at this time (3).

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# CHAPTER IV — SOLID WASTES

## RECYCLING AND REUSE

By Martin F. Nahlen, Capt, USAF

*Introduction*

The idea of recycling and reuse is becoming increasingly important as our now natural resources are being used up due to population increase, the desire for a higher standard of living, and advances in technology which can provide convenient appliances at lower prices. Air conditioners, dishwashers, electric can openers, and others create an increased energy demand in the home and industry. In order to increase sales and keep steady customers, the industry providing convenience items manufactures built-in obsolescence to appliances sold to the public. It is almost impossible to repair an electric frying pan if some internal part fails, and if you do get it fixed then the price is almost equivalent to replacement cost.

High standard of living creates more leisure time for the average citizen. In order for the average citizen to fully utilize and enjoy his free time, the industry has provided many ready to use products such as frozen and canned foods, beer and soft drinks in throw-away bottles and cans, milk in paper cartons, etc. Obviously throw-away packaging keeps the industry production at high level. If packaging was reuseable then the production would be reduced.

Throw-away packaging and built-in obsolescence have created several problems:

(1) Increased difficulty in trash disposal.
(2) Unprecedented demand on natural resources.
(3) Steadily increasing energy demands.

It is always possible to disagree as to what constitutes recycling and reuse. To clarify what is meant by these two terms in this chapter we will use the following definitions:

(1) REUSE—anything that can be reused for its originally intended purpose. For example, if a housewife goes to the store and buys a carton of Coke and she later returns the empty bottles to the bottling company to be refilled with Coke, then the bottles have been reused.

(2) RECYCLING—any form of energy, resource, or material that involves a conversion process to another or same form of energy, resource, or material. For example, if electric energy is used to spin a flywheel to store energy during low demand periods, and later during peak demand periods, the energy stored in the flywheel is converted back to electrical energy then we will consider the conversion process recycling.

According to our definitions reuse covers a relatively narrow area while recycling applies to any process where some sort of recovery is possible for further use.

In the past few years, energy shortages coupled with complaints from environmentalist groups concerned with pollution have forced the Federal, State, and Municipal governments to give serious consideration to recycling and reuse.

The United States has basically a free enterprise system which means that the industry cannot afford to reuse or recycle anything if it is not economical to do so. As long as raw materials are cheaper to use than alternative sources, recycling and reuse schemes will be severely limited. Transportation costs, which are controlled by the government, penalize recycling schemes for it is considerably cheaper to move iron ore than an equivalent amount of scrap steel.

*Recycling Municipal Waste*

The disposal of municipal waste is a problem that must be solved by each community. Since communities are considerably different, their waste disposal problems can be considerably different. A disposal method that is economical in one area may be completely infeasible in another. Landfill is usually the most economical method of waste disposal. Therefore, recycling must be brought to a competitive level with this method to provide municipalities with economic incentives to use methods other than landfill.

*Resource Recovery on the State of Technology*, a report prepared for the Council on Environmental Quality by Midwest Research Institute, February, 1973, discusses five general categories which can be used to recycle municipal wastes.

*Energy Recovery Processes*

One way to eliminate municipal wastes is to use high temperature incinerators. Incineration produces tremendous amounts of heat energy, which if not used or harnessed in some manner, is completely wasted. The only beneficial result then is a considerable reduction in municipal waste. Heat recovery incinerators have been used in Europe for many years. Heat recovery incinerators can be used to produce steam which can be sold commercially to heat office buildings, apartment houses, and even private residences.

One such plant is located in Chicago. The plant was designed to burn 1600 tons of refuse per day. The heat from this plant is converted to steam which is sold locally. The plant construction was started in 1969 and as of the spring, 1972, the reliability of the plant has been so poor that the steam could not be sold to customers. The design of the plant is similar to several other large incinerator plants in large European cities. The major components were designed and built in Germany and shipped to Chicago for assembly (8:17). Nevertheless, problems were encountered with burning excessively wet refuse and boiler corrosion. Of course start up problems can be expected since experience with this type of a plant is very limited in this country.

Obviously steam or recovered heat can be used for other applications. The city of Ansonia, Connecticut, uses recovered heat to dry sludge from the city's water pollution control plant. The sludge from the pollution control plant contains less than 10% solids and is fed directly into a spray drier and the dry product (less than 13% moisture) is pneumatically conveyed to the furnace where it is burned in suspension. The Oceanside plant at Hempstead, New York, uses recovered heat to desalinate ocean water for its own use. A proposed plant in

Hamilton, Ontario, will produce steam to run shredders (8:8).

*Fuel Recovery*

The main purpose of the fuel recovery process is to burn municipal wastes in conjunction with fossil fuels in industrial furnaces. This method recovers thermal energy stored in municipal wastes.

A 300 tons per day (TPD) plant was constructed by Union Electric Company in St. Louis with partial funding from EPA to process refuse supplementary fuel for electrical power plants. The milled refuse is pneumatically fed to the power plant where it is burned with pulverized coal. The refuse and the coal are injected into the furnace by separate nozzles. The refuse in this particular plant provides 10 to 20 percent of the fuel (8:8).

Another method to recover thermal energy from municipal refuse has been proposed by A. M. Kinney, Inc., a consulting firm. The Kinney system would use a hydropulper to convert all pulpable materials into an aqueous slurry. The hydropulper would continuously eject all non-pulpable material which would then be fed to a drum washer and then to a magnetic separator where all the ferrous materials are recovered. The pulped material would be fed into a liquid cyclone where non-fibrous materials would be removed. Then the slurry is de-watered and compressed into a cake with a 50% moisture content. The solid cake can be used in industrial boilers with or without additional processing depending on the type of boiler. A. M. Kinney estimates that the compressed cakes can provide 5 to 20 percent of the heat to a conventional boiler (8:8, 9).

At this time, the Kinney System is only in design stages; however, the feasibility of wet grinding has been satisfactorily demonstrated by the two years of a pilot plant operation of Black-Clawson Solid Waste Disposal Plant in Franklin, Ohio. A. M. Kinney conducted feasibility studies of using pulped, de-watered refuse cakes. These refuse cakes are similar to bagasse and bark (with a moisture content of 40 to 60 percent) which have been used successfully as a boiler fuel in pulp and sugar mills. Since the pulped refuse has better homogenity, smaller particle size, and more uniform water content, there is no reason to believe that it cannot be used successfully as a boiler fuel (8:9).

*Generation of Electricity*

Combustion Power Company, Menlo Park, California, is developing an energy recovery system from municipal wastes. The system is designed to shred solid waste materials and then burn it in a high pressure, fluid bed combustor. The hot gases from the burning process are used to drive a gas turbine generator to produce electricity. The plant was in the pilot stage when several problems were discovered. The fluid bed combustor suffers from an agglomeration of bed material particles. This places an upper limit on the fluid bed operating temperatures. The impingement of aluminum oxide particles on the exhaust system leaves deposits, and the fluid bed material suffers from elutriation. These problems have caused several design changes. The horizontal combustor has been replaced by a vertical combustor unit, and an aluminum removal chamber has been added between the combustor and gas cleaning train to eliminate the deposit problem. How well these changes are going to work is not yet known (8:9, 10).

*Materials Recovery Processes*

The Franklin, Ohio, Black-Clawson Plant uses a hydropulper to recover pulpable materials from the incoming municipal wastes. Municipal waste is made up of 40 to 50 percent of cellulose. Most of this cellulose is paper. The hydropulper receives all incoming wastes, except large bulky items (refrigerators, autos, etc.). Materials such as food, paper, plastics, rubber, rags, and wood are mixed with water and pulped. Heavy objects fall to the bottom of the pulper and pass through a magnetic separator to recover ferrous materials. An air classifier will be used to separate aluminum and glass. An optical sorter will be used to separate colored glass from clear glass (8:10).

As of this writing, the Franklin plant recovers only magnetic materials and paper pulp. The plant burns about 32% of the incoming waste. Non-ferrous materials and glass are disposed of as landfill. The pulpable materials are used for products like asphalt roofing felt. The Franklin plant has experienced problems with liquids and fines in their pulp and are in the process of adding equipment to reduce these contaminants.

Franklin Institute, of Philadelphia, Pennsylvania, is in the process of developing a dry paper separator. The incoming refuse is shredded and hurled in a horizontal direction by a rotating wheel. A downward blast of air causes the lighter materials to drop out first (paper and plastic) and the heavier materials last. A plastics separator removes the plastic from the paper. Laboratory tests show that 90 to 95 percent pure paper is achieved with this method (8:11).

The Bureau of Mines, College Park, Maryland, has developed a process to recover incinerator residues. The recovered materials are metals and minerals. The process uses conventional and proven mineral engineering equipment. The products of the process are metallic iron concentrates, nonferrous metal composites, glass fractions, and fine carbonaceous ash. A pilot plant will be built in Lowell, Massachusetts (8:11). How successful the process will be remains to be seen, but it is a step in the right direction to conserve and reuse some of our natural resources.

*Pyrolysis Process*

The pyrolysis process is basically a process of distilling organic materials. It is frequently referred to as "destructive distillation". In the pyrolysis process, organic materials are heated under pressure either in the absence of oxygen or in a controlled oxygen environment. (The temperature range normally from 1000°F. to 2000°F). The temperature, pressure, and the amount of oxygen regulate the product composition. Generally the products of pyrolysis come in 3 categories:

(1) Gaseous products consisting primarily of hydrogen, methane, carbon monoxide and carbon dioxide.

(2) Tars and oils which are liquid at room temperatures including organic chemicals like acetic acid, acetone, and methanol.

(3) Solids consisting of "char" (almost pure carbon) and inerts like glass and metals.

Garrett Research and Development Company has designed a resource recovery system for the city of San Diego, California, utilizing the pyrolysis process. The system incorporates all receiving, handling, shredding,

and classification operations for solid waste. The metals and glass must be removed before pyrolization can begin. In order to obtain high yields of oil and gas, the waste fed into the reactor must be dry, pure organic material of small particle size. Under laboratory conditions the process can produce over one barrel of oil per ton of input refuse or 6000 cf of gas with a heating value of 800 BTU/ft$^3$. The San Diego plant will be able to process 150 tons of refuse per day (8:11-13).

The Monsanto "Landgard" system was operated in St. Louis, Missouri, for three years. The system was primarily designed for waste disposal. The Landgard system has all the operations for receiving, handling, shredding, and pyrolyzing solid waste. It can quench and separate residue from pyrolysis, generate steam from waste heat, and purify the off-gases. The St. Louis plant has a 35 TPD capacity and was used basically as a pilot plant to show the feasibility of pyrolysis process. Steady state, long term operations were not performed, but individual components were thoroughly tested. It laid the groundwork for 500 TPD plant in Baltimore, Maryland (8:13).

Professor Richard Bailie at the University of West Virginia has developed a twin fluid bed pyrolyzer system. The first unit acts as a pyrolyzer operated at 1400°F where gas, char, and some tar are produced. The gas has a heat value of 400 BTU/ft$^3$. The gas and tar are burned in the second unit used as the combustor to provide heat for the pyrolyzer. Each unit has been operated successfully on an individual basis, but has never been integrated into an independent system. This is the basic system that the city of Charleston, West Virginia, proposes to adopt (8:13).

Hercules, Inc., has designed combinational resource recovery system for the state of Delaware. This system will first remove ferrous materials from residential refuse, then non-compostable organic materials will be pyrolyzed, and the rest will be mixed with sewage sludge and composted at the Fairfield digestion unit. Industrial and commercial wastes will be treated the same way (8:14).

Another pyrolysis process implemented in the city of Kenwick, Washington, is somewhat different. The two TPD plant was constructed by Batelle Northwest. The plant operates on batch basis. The process uses a vertical reactor where the waste materials are progressively dried, charred, and finally oxidized at relatively low temperatures, under controlled conditions. The refuse is processed in three transformation stages. The solids move down while the hot gases rise. The solid char, product of the pyrolysis in the upper part of the reactor, is oxidized in the lower part by a mixture of oxygen and steam. The hot reaction gases use and cause charring of the entering waste material. The residual heat in the gases dry the refuse at the top of the reactor. The gases leaving the reactor contain hydrogen, carbon monoxide, carbon dioxide, water vapor, and hydrocarbons. These gases contain no ash and can be burned in a secondary burner or they can be processed further into hydrogen and carbon monoxide mixture which can be used to produce methane (8:14).

*Composting*

Composting is nothing new; it has been used for centuries. However, in the United States commercial composting has not been very successful because the market is very limited. Presently, there are only two composting operations in the United States that have been successful (8:15).

The Altoona FAM, Inc., Altoona, Pennsylvania, uses the Fairfield-Hardy Process. In this process, the refuse is ground in a wet pulper. After the grinding process has been completed, the refuse is de-watered and fed into a digester for a five-day period. The digester is a circular tank where augers are used to provide stirring, and air is supplied by blowers fed to the bottom of the tank by pipes. The method apparently provides a superior humus product, and the process is more automated than many others (8:15).

Ecology, Inc., Brooklyn, New York, uses the Varro Composting Process. The Varro process is unique because the digester can compost refuse that has a paper content up to 90%. Most composting processes have to remove the paper and dispose of it in some manner. Secondly, only ferrous material are removed after shredding. The rest of the refuse is fed into the digester for composting. Thirdly, the digester permits control of the variables in the decomposition process and thus produces humus which is more homogenous. Ecology Inc., adds nutrients to the compost such that it can be sold as a fertilizer (8:15).

*Chemical Systems*

Chemical waste processing is in its infant stage. Five chemical methods have been suggested to convert refuse into useable products. The methods use only the cellulosic (paper) portion of the refuse.

Hydrolysis of cellulosic waste into protein and glucose is the only method out of five that has been tested on pilot plant level. Hydrogenation and wet oxidation have been studied in laboratories whereas photo degradation and anaerobic digestion are no more than ideas (8:16).

A pilot plant was constructed at the Louisiana State University to convert waste sugar cane bagasse into single cell protein. The plant has five process sections—cellulose handling, treatment, sterilization, fermentation, and cell harvesting. The plant was designed for both batch and continuous operation. The plant has produced single cell protein with a crude protein contact of 50 to 55 percent (8:16).

*Economics*

The Midwest Research Institute Study (8) discusses and makes economic comparisons for the waste recovery processes discussed above; however, any economic comparison is only of temporary value. As the technology of resource recovery process improve, their cost will diminish. Another factor that has a great impact on the resource recovery processes is the price of industrial raw materials. Already there is an energy shortage which means that the price of natural gas and oil will increase over time, and thus making, at least heat recovery more attractive.

The pyrolysis is a relatively expensive method of producing oil and gas, but as the price of oil and gas goes up this method will become more attractive economically. At the present time all resource recovery processes have to compete with sanitary landfill, but the price of real estate is increasing, and sites for landfills will be further away from communities thus increasing transportation costs. It will not be long when resource recovery methods will be the only sensible way to handle municipal wastes.

*Industrial Advances in Recycling and Reuse*

There are very few people, if any, in the United States who do not use electricity. The average community in this country is so totally dependent on electricity that even an interruption of this form of energy for a few days will render a community helpless. The major problem with electrical power is that the demand for it is not constant. The demand is higher during certain periods of the day than others. During periods of peak demand some areas do not have enough capacity to meet this demand. When this happens the result is what is known as a "brownout". Most utilities operate a multi-tiered system. Nuclear and new fossil power plants make up the first tier. These plants operate 24 hours a day flat out. This is usually sufficient to provide enough power for night time needs. In the morning when offices open and factories start up, the power demand increases. Now the second tier is brought on line. These are old power plants which use more fuel, and therefore are more costly to operate. At times even this is not sufficient. On hot summer days when air conditioners are going full blast or on cold winter days when thermostats are turned on high, the power companies must bring out the third string. The third string consists of gas turbines. Gas turbines are relatively cheap and flexible, but they are very expensive to operate because of very high fuel consumption (2:1).

One answer to this problem is to store the electricity during off-peak hours and use it during peak demands. Unfortunately electricity is not readily storable. Several methods have been devised to convert electrical energy to some other form and then converted back when the need arises. However, recycling electricity is still rather crude.

One method already in use is pumped water. Water is pumped uphill from a huge reservoir into another reservoir during hours of low demand. When electricity is needed the water is allowed to run back through the pumps which now act as generators. The method is not particularly efficient; about one third of the electricity used to pump water uphill is lost, but it is still cheaper than using gas turbine generators. The drawbacks are, of course, large amounts of land and mountainous terrain. The plant is generally located a considerable distance from the users thus increasing transmission costs. The whole operation requires huge capital outlays. The largest system in the world is owned by Consumer Power and Detroit Edison in Luddington, Michigan. The system costs $300 million and holds 27 billion gallons of water and requires about 1800 acres of land (2:17).

A much more compact system, now in the research and development stage, is the hydrogen storage system. A direct current flows through an electrolyzer where water molecules are broken up into hydrogen and oxygen atoms. Hydrogen is pumped into a tube containing iron-titanium. This metal has a high affinity for hydrogen atoms and forms a bond called metal hydride. When this tube is heated, the iron-titanium releases hydrogen gas which is piped into a fuel cell where electricity is produced when hydrogen reacts with oxygen. At the present time, only 18% of the electricity is recovered, but researchers believe the efficiency can be increased to 50% (2:17).

Another method of storing or converting electrical energy is to spin a flywheel during off-peak hours. When additional electricity is required, the energy from the flywheel can be used to generate electricity. The main drawback of this system is that it is very difficult to find materials that will not fly apart at the high speeds required (2:17). The energy shortage created a need to produce oil and gas from coal and shale located in the Western United States, but the conversion requires vast amounts of water which are not available. Presently in areas like Colorado, Utah, Wyoming, and Montana, most of the water is used for irrigation, and the local residents and farmers do not look favorably on the wholesale use of their water for energy conversion (6:1). To tap these energy sources, the only answer at the present time seems to be the recycling of water. However, the technology to accomplish this feat does not exist at the present time.

American aluminum companies import most of the bauxite from Jamaica, Dominican Republic, and Haiti. Dominican Republic raised the taxes on bauxite from $2.50/ton to $9.07/ton (8:17). Aluminum is already being recycled in this country, and tax increases by bauxite producing countries will increase the profitability of recycling aluminum in the U. S. Australia also produces vast amounts of bauxite, but it is considerably further than Dominican Republic, Haiti, and Jamaica, thus these small nations still have the competitive edge (12:18).

Lower speed limits in this country have resulted in reduced sales for items like fenders and bumpers but has increased business for tune-ups. However, the reduced accidents have resulted in fewer donors of kidneys for transplants. Thus the reduced speed limits are reducing kidney reuse (3:1).

Plastic industry has developed a process whereby it is possible to produce a self-destruct plastic thus alleviating the litter problem. Some companies produce biodegradable garbage bags and plastic utensils. Acceptance of degradable plastics in the United States is low compared to Europe and Japan (4:1). If biodegradable plastics find high acceptance then problems associated with recycling plastics will disappear. Sanyo Electric Company in Jusatsu, Japan, has developed a process to recycle plastic into oil. The plant is able to convert 4.9 tons of plastic into 3.43 tons of kerosene. The only problem with the process is the high cost (5:1).

Who says that recycling is not profitable? A junk peddler collected and sold old batteries for their lead content and claimed an income of $4200. The IRS felt that the figure was too low and claimed that the peddler's income was $77,870. The IRS won the suit (20:1).

Countries of East European Economic Community (COMECON) are building three factories in Cuba which will be capable of manufacturing paper from sugar cane fibers (19:5). Unfortunately the article does not state if paper is produced after sugar has been retrieved. If it has, then the process could be defined as recycling.

Gulf Oil of Canada feels that they have discovered a process where they can replace half the asphalt in road construction with sulphur. The laboratory tests show that the resulting surface is the same color but has double the stability and a higher resistance to water and low temperatures. The process involves replacing half the asphalt with molten sulphur using standard paving equipment (11:27). This is not directly recycling or reuse, but it does conserve oil products and another use for sulphur has been developed. Since sulphur compounds are some of our main pollutants, it may be

feasible in the future to recover sulphur from those compounds for paving roads.

Potlatch Corporation plans to build an automated plywood mill in Idaho which is capable of producing 204 million square feet of ¼ inch plywood annually. The facility will produce a new type of plywood using reconstituted wood for structural cores. It will also use lower quality logs that were previously unacceptable (13:8). This again is a step in the right direction to reduce waste and comes under the heading of reuse, using materials previously unacceptable.

Indirectly it can be said that if coal is converted to gas, this comes under the heading of recycling. It is taking coal which is unusable in a gas furnace and changing it into gas which can be used. Continental Oil manages a project in Scotland that produces gas from coal. The process produces methane from coal-gas which has the same heat value as natural gas. The plant in Scotland is capable of producing 25 million cubic feet per day. The gas will be supplied to local residents for several weeks to evaluate the methanization process and equipment. Conoco said that two U. S. projects are planned on the information received from the Scotish project. The two planned projects would be able to produce 250 million $ft^3$ /day (14:6).

Universal Oil claims that they have developed a method of recovering oil from coal. The process involves using pulverized high sulphur coal with a solvent and hydrogen. The mixture is then subjected to high temperatures and pressures. Other companies have used similar methods but the result has been a liquid-like asphalt because it is very difficult to remove the ash-like substance from the pulverized coal. Universal Oil says that they have solved the problem, and the result is over four barrels of petroleum-like liquid from one ton of coal. This liquid can be refined into gasoline or other fuels using standard refining procedures (16:7).

Two Goodyear scientists have developed an automobile fuel that is 72% gasoline, 25% t-Butyl alcohol and three per cent water. The fuel is still in the experimental stage but the results have been very encouraging. This fuel has a high octane rating and does not contain any lead. When used in a standard V-8 engine it provides a 65% reduction in pollutants without any expensive pollution control devices. Since the fuel burns cleaner, it reduces engine deposits and thus increases engine life (15:13). Since the engine life is increased, a normal individual will need fewer engines and automobiles during his lifetime. The result is equivalent to reuse.

Biospherics, Inc., has developed a process to remove phosphorous from waste waters. The price of phosphates used in fertilizers has risen considerably in the past year. As a matter of fact the price of phosphate charged by Morocco is now so high that under-developed nations cannot afford to buy fertilizers. Will this process help to reuse the reclaimed phosphourous in fertilizers (21:3)?

Wheelabrator-Frye plans to construct a coal purification plant. The process involves taking high sulphur coal, pulverizing it, and mixing it with a solvent. Then the mixture is converted into a gas, a liquid, and then back into a solid. The result is ash-free, sulphurless coal. The original plant will have a 1,000 TPD capacity, and if it is successful it will be expanded to produce 10,000 TPD of sulphur-free coal (17:7).

Wheelabrator-Frye has also signed an agreement with Peru to construct a plant that is capable of producing newsprint from sugar cane bagasse. Bagasse is the waste material left over after the sugar has been extracted from the cane. The plant is scheduled to begin production in 1977 with a capacity of 30,000 tons of newsprint annually, which will be increased 112,000 tons by 1981 (18:15). Sugar cane bagasse is presently a waste material which now can be recycled into a useful product.

Wheelabrator-Frye and nine greater Boston communities have tentatively agreed on a solid waste disposal system with Resco. The nine communities will deliver their waste to the Resco plant and will be paid $13.00/ton for the first year for their waste materials. The contract will be renegotiated annually. The waste materials will be used to provide steam to a General Electric Company plant in Lynn, Massachusetts. The plant will eventually have a capacity to process 1,200 tons of refuse per day. The project, completely financed by private capital, is the first of its kind in the United States (19:14).

*Summary*

Many of the processes discussed earlier will change their form due to economic conditions and advances in technology, but one thing we can be sure of, as time passes and our natural resources are used up, recycling and reuse will become a way of life. Instead of throwaways we will have repairables. It is a law of nature that nothing is lost but only changes form. Since this is true, we should never run out of natural resources—we will just keep changing their form and using them over and over again. We just have to learn to accomplish this task quickly and efficiently. For example, if the price of scrap paper jumped from $9.50/ton to $23.00/ton in Fort Worth, Texas, city's garbage collection department could expect to make $250,000 selling paper (1:2), a classical example of economic impact on recycling.

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# CHAPTER V — ENERGY

## NUCLEAR POWER

By William W. Whittenberger, Capt, USAF

*Introduction*

In 1939, scientists discovered that uranium nuclei would split into two or more fragments with an accompanying release of energy, after absorbing a neutron. This process, called fissioning, would subsequently release an average of two or three neutrons per fission. If at least one of these released neutrons could be made to cause another fission, the process could be made self-sustaining with a continuous production of energy. The device in which the continuous nuclear fissioning process is initiated, maintained, and controlled is called a nuclear reactor and on 2 December 1942, the first nuclear reactor was operated by Enrico Fermi (1:1). Since that time, major efforts have been made by both private industry and government to develop this source of energy for commercial purposes.

### NUCLEAR REACTOR THEORY

*The Fission Process*

Since 1939, three elements have been identified as potential nuclear fissioning materials for a nuclear reactor; uranium-233, uranium-235, and plutonium-239. The most commonly used material is uranium-235. The basic fission equation for uranium-235 can be represented as follows:

$_{92}U^{235} + {}_0n^1 \rightarrow {}_{92}U^{236} \rightarrow$ 2 fission fragments + 200 Mev energy + 2.5 $_0n^1$

Where $_{92}U^{235}$ is uranium-235; $_0n^1$ is a neutron; the fission fragments are two or more new elements, where total protons add to 92; and 200 Mev is 200 million electron volts of energy.

The fission fragments subsequently release free electrons called beta particles and gamma rays which are energy packages (photons) of higher energy than X-rays. Table 1 lists the distribution of fission energy among the various products of the fissioning process (2:Ch. 1:4). All energy released within the reactor is ultimately transferred to heat through the interaction of the fission products and the surrounding materials.

*Nuclear Reactor*

The basic components of a nuclear reactor are the core, collant, moderator, reflector, control mechanism, and shield.

TABLE 1
Distribution of Fission Energy

| | Energy (Mev) |
|---|---|
| 1. Fission fragment | 168±5 |
| 2. Instantaneous gamma-ray | 5±1 |
| 3. Kinetic energy of neutrons | 5±.5 |
| 4. Beta particles | 7±1 |
| 5. Gamma-ray from fission fragments | 6±1 |
| 6. Neutrinos | 10 |
| Total Fission Energy | 201±6 |

The core of the reactor consists of the fissioning material, usually uranium-235. The fissioning material is usually mixed with some other material such as aluminum or thorium, rolled into a sheet and then sealed by an outer coating of material such as zircaloy. In other cases, the fissioning material is made in the form of ceramic pellets continuing uranium-235 dioxide. These pellets are placed in a closed stainless steel tube. The core is then made up of many of these tubes arranged so that a continuous fissioning process can exist.

The fissioning process generates large quantities of heat which must be removed in order to prevent melting of the core. This is usually accomplished by using some form of coolant such as water, a mixture of sodium and potassium called NaK or liquid sodium.

The moderator, reflector, and control mechanisms are utilized to control the neutron population such that the fissioning process is self-sustaining.

The shield is made of high density material to protect the personnel from the high energy products of the fissioning process. Figure 1 illustrates a typical nuclear reactor.

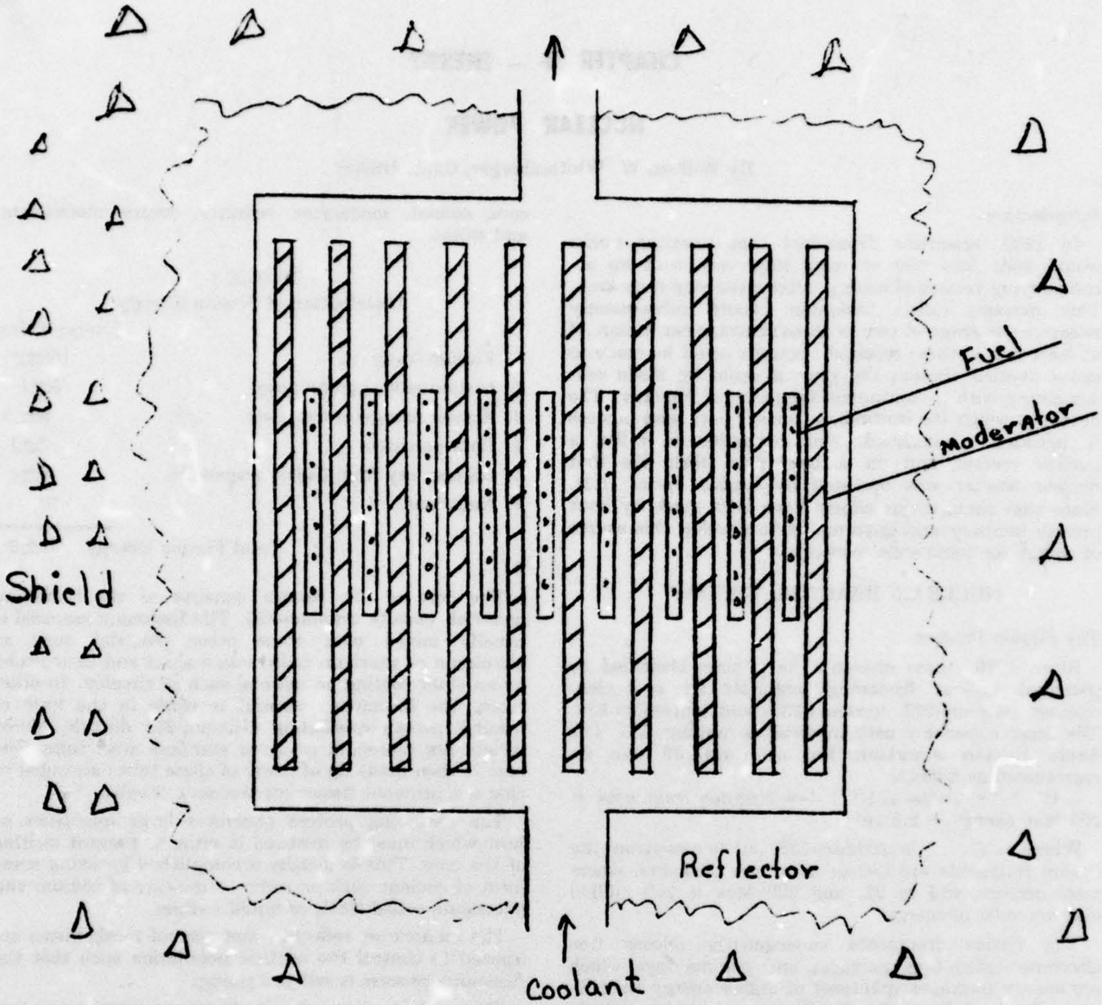


**Figure 1. Reactor Core.**

## COMMERCIAL APPLICATIONS OF NUCLEAR REACTIONS

The most common application of nuclear power is for the generation of electrical power; however, other applications include manufacturing and experimentation.

### *Electrical Power*

Since the major by-product of nuclear fissioning is energy and that energy ultimately results in heat, nuclear reactors have been coupled with electrical generators to produce electricity. Figure 2 shows a typical nuclear powered electrical generation plant. Once the coolant leaves the core of the nuclear reactor, the coolant is passed through a heat exchanger whereby the heat of the coolant is utilized to generate steam for the electrical generation process. This steam is passed through a turbine which transfers to energy of the steam to the mechanical motion of the turbine. The effluent from the turbine is then cooled, condensed and passed back through the reactor's heat exchanger to complete the cycle. The cooling of the turbines' effluent is normally accomplished by passing well, river, or lake water through the heat exchanger and then dumping the heat back to the environment by flowing the water into the river, lake, settling ponds or through cooling towers.

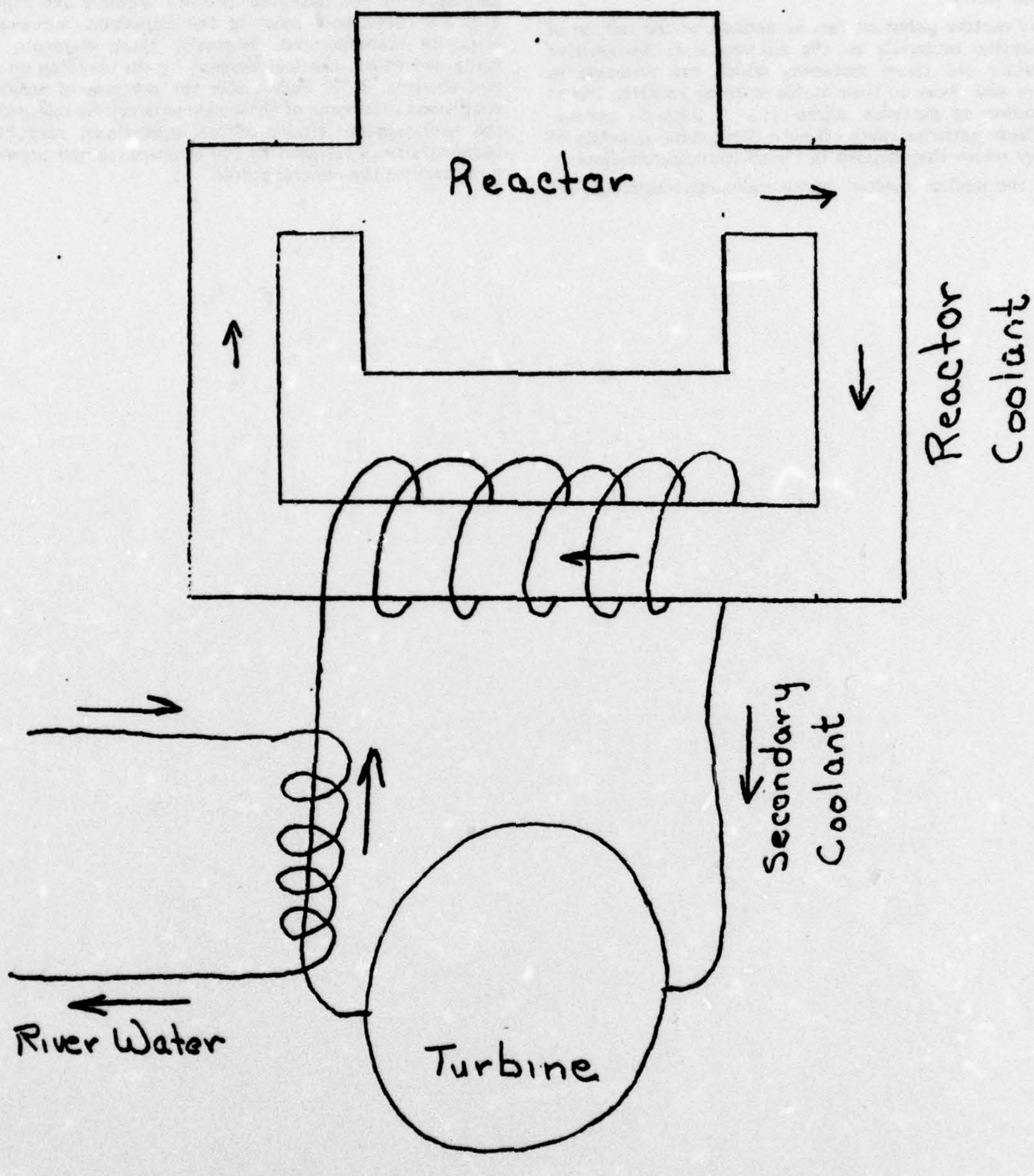


**Figure 2. Coolant System for a Nuclear Electrical Generation Plant.**

***Manufacturing***

**The nuclear reactor can be utilized anywhere large quantities of heat are needed for manufacturing processes. Some future applications might be heating of cities, airports, and roads. Other manufacturing processes might utilize the products of the fissioning process to create their products.**

***Experimentation***

**Much effort is underway to utilize test reactors to determine the effects of radiation and heat on materials. Other applications are nondestructive testing of *materials using* neutron radiography and isotope identification procedures.**

## ENVIRONMENTAL POLLUTION BY NUCLEAR REACTORS

***Introduction***

**There are two basic types of pollution associated with the operation of a nuclear reactor: radioactivity and thermal.**

*Radioactivity*

Radioactive pollution can be defined as the release of radioactive materials to the environment. Radioactive materials are those materials which are unstable in nature and decay to their stable state by emitting one of the following particles; alpha-$_{2}He^{4}$, Beta-$\beta$, gamma-$\gamma$. These particles carry off with them some quantity of energy which they deposit in the surrounding medium.

In the nuclear reactor, many radioactive elements are generated by the fissioning process. Table 2 and Figure 3 (2:5-6) illustrates most of the important radioactive elements manufactured. Normally these elements are contained within the fuel element by the cladding on the fuel element. It is only under the severest of accident conditions that some of these elements can be released to the environment. Under normal operations, very little radioactivity is released to the atmosphere and presents no hazard to the general public.

Table 2 - Production of Important Fission Products in a Reactor

| Fission Product | Activity (Curies) after selected periods of continuous operation of a reactor at a power level of 1,000 kilowatts | | |
|---|---|---|---|
| | 100 days | 1 year | 5 years |
| Kr - 85 | 53 | 191 | 818 |
| Rb - 86 | 0.25 | 0.26 | 0.26 |
| Sr - 89 | 28,200 | 38,200 | 38,500 |
| Sr - 90 | 402 | 1,430 | 6,700 |
| Y - 90[(a)] | 402 | 1,430 | 6,700 |
| Y - 91 | 34,800 | 48,900 | 49,500 |
| Zr - 95 | 32,900 | 49,200 | 50,300 |
| Nb - 95(90 H)[(a)] | 446 | 687 | 704 |
| Nb - 95(35 D)[(a)] | 20,900 | 48,200 | 50,500 |
| Ru - 103 | 25,100 | 30,900 | 31,000 |
| Rh - 103[(a)] | 25,100 | 30,900 | 31,000 |
| Ru - 106 | 753 | 2,180 | 4,220 |
| Rh - 106[(a)] | 753 | 2,180 | 4,220 |
| Ag - 111 | 151 | 151 | 151 |
| Cd - 115 | 4.8 | 5.9 | 5.9 |
| Sn - 117 | 83 | 84 | 84 |
| Sn - 119 | < 24 | < 64 | < 100 |
| Sn - 123 | 4 | 9 | 10 |
| Sn - 125 | 100 | 101 | 101 |
| Sb - 125[(a)] | 12 | 43 | 139 |
| Te - 125[(a)] | 5 | 34 | 136 |
| Sb - 127 | 787 | 787 | 787 |
| Te - 127(90 D)[(a)] | 146 | 260 | 277 |
| Te - 127(9.3 H)[(a)] | 808 | 922 | 939 |
| Te - 129(32 D) | 1,410 | 1,590 | 1,590 |
| Te - 129(70 M)[(a)] | 1,410 | 1,590 | 1,590 |
| I - 131 | 25,200 | 25,200 | 25,200 |
| Xe - 131[(a)] | 250 | 252 | 252 |
| Te - 132 | 36,900 | 36,900 | 36,900 |
| I - 132[(a)] | 36,900 | 36,900 | 36,900 |
| Xe - 133 | 55,300 | 55,300 | 55,300 |
| Cs - 136 | 52 | 52 | 52 |
| Cs - 137 | 300 | 1,080 | 5,170 |
| Ba - 137[(a)] | 285 | 1,030 | 4,910 |
| Ba - 140 | 51,500 | 51,700 | 51,700 |
| La - 140[(a)] | 51,300 | 51,700 | 51,700 |
| Ce - 141 | 43,000 | 47,800 | 47,800 |
| Pr - 143 | 45,000 | 45,300 | 45,300 |
| Ce - 144 | 9,860 | 26,700 | 44,000 |
| Pr - 144[(a)] | 9,860 | 26,700 | 44,000 |
| Nd - 147 | 21,800 | 21,800 | 21,800 |
| Pm - 147[(a)] | 1,290 | 4,900 | 16,000 |
| Sm - 151 | 9 | 37 | 175 |
| Eu - 155 | 23 | 74 | 207 |
| Eu - 156 | 108 | 109 | 109 |
| TOTAL | 563,691 | 693,573 | 767,547 |

[(a)] Daughter product.

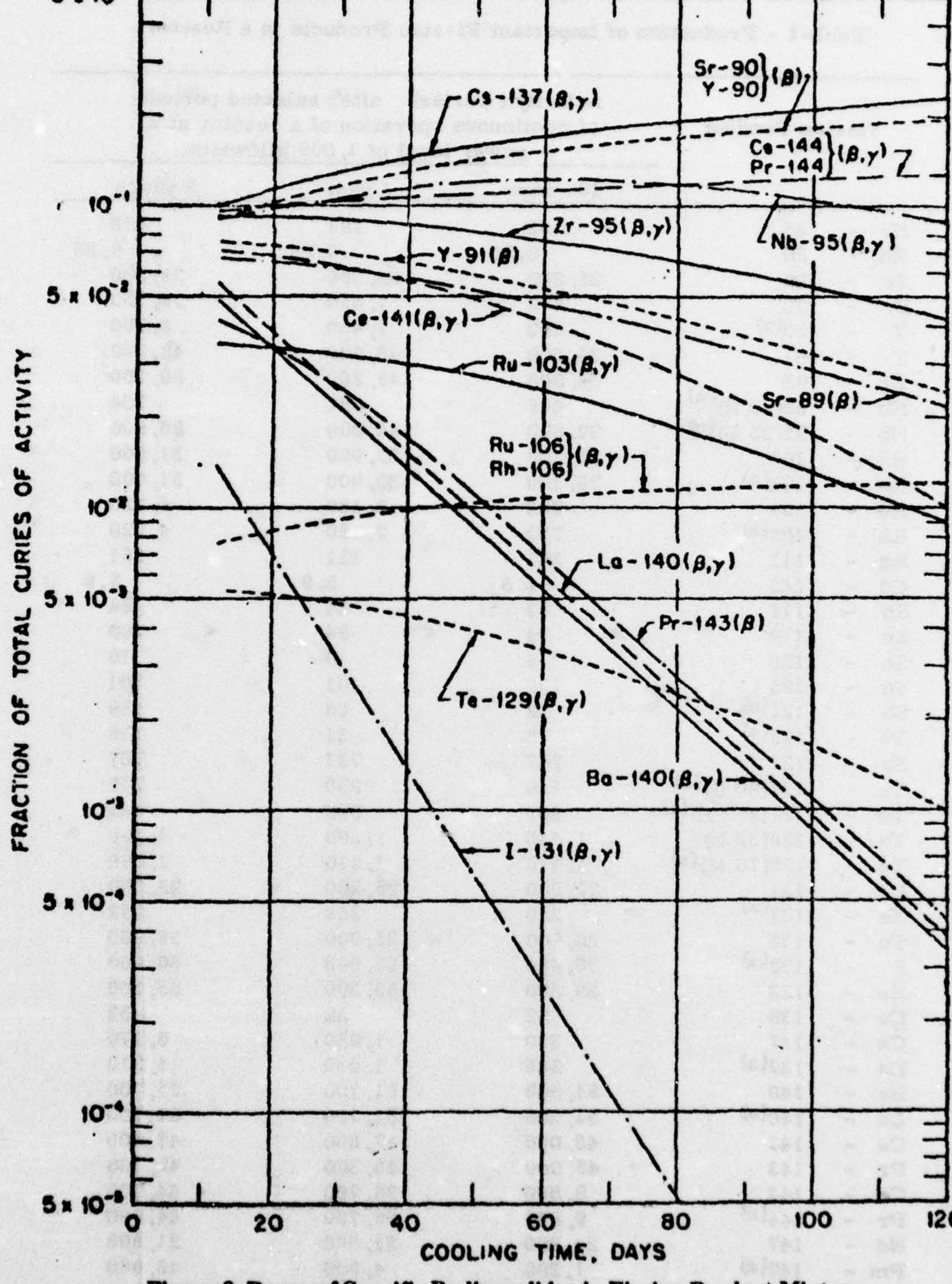


**Figure 3. Decay of Specific Radionuclides in Fission Product Mixture.**

There are two general types of accidents that can be postulated to occur at a nuclear reactor: An external accident, that is loss of coolant due to failure of the coolant system by some means such as earthquakes, pipe failures, aircraft crashing into the reactor, external bombing, etc. or an internal accident, that is the reactor controls fail to regulate the neutron population such that the coolant is caused to vaporize. All reactors are designed to guard against these measures and the safeguards used to date have resulted in no major accidents in the commercial areas. However, if one of these types of accidents were to occur, then the possibility of a release of radioactivity from the core could be expected since the nuclear core has sufficient heat generating capability to melt the fuel elements. Some of the radioactivity is gaseous in nature and would be released to the atmosphere of the reactor containment shell. The containment shell is an engineered safeguard to contain the possible release of any radioactive materials. Since nothing in nature is perfect, it is possible then to release quantities of radioactive materials to the environment. Some reactors are designed with many other safeguards such as emergency cooling water, air scrubbers and effluent filters. Other measures such as continuous inspection by plant and government employees help to insure that the probability of having this type of accident are kept to a minimum.

The consequences of releasing any radioactive materials would be to pollute the air, ground, and water in the surrounding area with radioactivity. The maximum quantities that would be released would be a function of the operating time till the accident, type of accident and the operating power level. Of all the radioactive materials present, the most serious to man are the radioactive iodines and strontium-90. These particles are gaseous in nature and tend to get deposited in water, on plants and on the soil. Plants then absorb these particles and place them in the food chain. The real danger to man comes about because they tend to remain in bones and glands, depositing energy in the regions they are located causing the cell structure to degrade. The other radioactive particles present in reactor cores could be dispensed into the immediate area causing the area to become contaminated. Since it is difficult to clean up this sort of material, the area would be evacuated of inhabitants and become a sterile area.

*Thermal Pollution*

As a nuclear reactor is operating, it constantly is generating heat. Some of this heat is utilized in the production of electricity and the rest dissipated to the environment. In the typical modern power plant producing 200 megawatts of electricity, 900 to 1000 megawatts of heat are produced per hour of operation. This means that between 600 and 800 megawatts of heat per hour are released to the environment by some means; cooling towers, rivers, lakes, or ground heating systems. This presents a problem for the ecologist since the ecology of the surrounding area is often changed by this discharge of heat. Where trout once lived now bass survive. The overall effect is to change the habitat of the area to that of warmer areas. Whether this is good or bad depends on the party being asked.

*Environmental Impact*

Because of the inherent problems of environmental pollution, nuclear power plants are often located in remote areas of the country. This presents many problems for the surrounding communities due to the availability of electrical power not originally in the area. Towns develop close to the power plant bringing in families that need more services than the community can provide. The economic base of the community is often raised creating higher prices for goods and services than were previously paid. The social and political ties of the community are changed by the increase in the urban population. In many cases, the architecture of the nuclear plant will not resemble the natural habitat. These are all problems that must be faced in the construction and utilization of nuclear power for electrical generation facilities.

## SUMMARY

As the need for more energy increases and the conventional fuel supplies dwindle, nuclear power will become more attractive as an energy source. This section was designed to illustrate the environmental impact of such a power source on the community in which it is located. It is not intended to condemn nuclear power, but to illustrate the potential problems. Nuclear power has been a vital source of electrical power since 1947 and through proper regulation and engineered safeguards has not presented a hazard to any of the communities in which it has been located.

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# CHAPTER V — ENERGY

## NON-NUCLEAR POWER

By James H. Lowry, Maj, USAF

*Introduction*

Energy is the indispensable element of a modern society's ability to do the things it wants to do (4:2). Through the efficient use of natural energy sources (other than animal power), productivity has been and can further be greatly increased. Energy stands firmly as one of the keys to economic growth, to the elimination of poverty, and to improving the quality of life (5:3). An abundance of energy nationally, such as we have been accustomed in the United States, also allows for our continued affluence, national security, confidence in our international associations, and increasing assistance to the less developed nations of the world.

It is self-evident by the recent concern and attention of great numbers of people in the private and public sectors of our society that energy self-sufficiency as a nation is a paramount goal. The Atomic Energy Commission, among others, feels that in actuality, such a goal can be achieved by 1985 (4:viii). Intense exploration into the realms of the alternate non-nuclear sources of energy is also involved so this country seeks to attain self-sufficiency in its energy sources.

The importance of energy is accepted by the high governmental action regarding the development of a national energy policy. Such a policy would involve those activities having a direct impact upon the Nation's energy system, with the aim of increasing supply, reducing demand, or changing production and use patterns. The air of a national energy policy is to ensure that the Nation's ability to pursue its higher order goals is not unduly impaired by energy shortages (4:2).

The majority of energy consumed in the United States is in the form of electrical energy. While not a primary source of energy, electricity is produced from all of the primary sources of energy, including coal, oil, natural gas, water, and nuclear sources, and can also be produced from the so-called renewable sources of energy, geothermal and solar energy. While energy of all types is without substitute, electricity which uses the greatest amount of our energy sources is the very life blood of our economy. Until recently, we took our seemingly boundless electric resources for granted, never doubting that its basic sources were limitless. We found our faith unfounded. What results from the thorough analysis of the situation underlying the so-called "fuel crisis," is the discovery that we do not really lack for energy sources. Our deficiency lies in a lack of technology needed to extract the energy we need from sources we know and have long known to exist all around us. There is no shortage of energy sources.

> The US has sufficient total proved domestic energy resources of the type currently in widescale commercial use to satisfy all projected energy demands until well beyond the end of this century (5:74)

Yet money, time, and a sense of urgency are needed to tap them.

Most experts believe that the three sources of new energy which demonstrate the greatest potential are solar, geothermal, and nuclear fusion sources (5:77). These correspond with the Federal Government's opinion as expressed by the House Committee Report in 1972 as part of those energy sources which do warrant the highest priority federal investment in research and development (5:16). Due to the current high costs of importing or exporting fuels, it is now economically feasible to develop new sources of energy, especially in regards to oil shale, tar sands, and geothermal energy (6:8).

We will deal at this time with those alternate sources of energy which appear worthy of our effort and concern, either warranted by economy (investment wisdom), availability (resource base), power value (Btu potential), the energy need, and lastly, and of course of prime concern, the environmental impact.

The technology apparently exists to develop many of these energy sources without requiring major technological breakthroughs (5:3). Current processes must of course be refined, but this effort can be approached confidently as the economic viability of the new porcesses are assessed. Given the necessary funds, solutions to our power shortages will be found by developing new methods and processes that will increase the efficiency of power use, reduce pollution from fuels of all kinds and provide energy supplies at costs lower than or at least similar to those being experienced using current techniques. How successful this effort will be is uncertain until the work is fully identified and/or completed. Hence, the research and development cost associated with a given problem cannot always be determined in advance (5:4).

Coincidentally with the development of new energy sources of power, our society must be concerned for the impact of each of them upon our world's environment (2:23). There is little justification for assuming that pollution must grow from the technology developing these new energy sources: replacing cars with modern electric-powered trains will drastically decrease air pollution and solid waste; generating electricity by nuclear plants anchored in the ocean will decrease both air pollution and the thermal deterioration of rivers and estuaries (1:278).

### ENERGY CLASSIFICATION (POINTS)

*Resource Base*

As noted earlier, a research effort into the development of a new energy source can be warranted by one of several considerations, or sundry combinations of them, such as economy, availability, power value, need, and environmental impact. However, a characteristic most crucial to any research and development effort, whether undertaken by the Federal Government or by private and/or commercial interests, is the "resource base" of the energy source. This is the physical size of the energy resource, domestically and internationally available. This is the starting point for establishing priorities for research and development of the resource. If the resource is in short supply, here in the United States and also abroad, there is little to be gained in spending excessive

time, effort, and money, on research development efforts. Further definitions regarding resource base may be useful in discussing this situation (5:25-26).

*Nonrenewable resource base* - this category defines the total quantity of the resource originally found in the earth's crust, and may be exhausted by man's use.

*Renewable energy source* - this category describes those resources which are not normally considered nonreplaceable, or are considered limitless, energy sources such as the sun, the wind, the ocean, and geothermal heat.

*Fuel or energy reserves* - this is a term used to identify the known part of the resource base that can be recovered economically with current technology.

*Identified recoverable resources* - this is the amount of the resource that can be extracted commercially at current prices and with current technology. An adequate amount of known geologic/technical information must be available so that the quantity of the resource and its geological setting is firmly known so that a high degree of certainty exists in our ability to extract and use it.

*Identified submarginal resources* - those resources on which not enough technology exists, or the price involved is too high, or some other restrictive factor prevents development of known resources at this time.

*Paramarginal resource* - these are resources that are believed to be producible at near current prices with existing technology.

*Probable potential reserve* - this term describes that category of recoverable resources which are on the boundary between identified and undiscovered deposits.

*Potential undeveloped resources* - this term covers those energy sources which are not extensively explored nor currently economically recoverable but which loom as very promising resources due to the size of their resource base and/or the intriguing state of technology relative to their production and use. Primary among these, and of principle concern in this study, are: oil shale, tar sands, geothermal, and solar energy sources (note: nuclear fusion fuels and thorium are also in this category but are nuclear in nature and will therefore not be discussed in this section 5:29).

## PRINCIPLE NEW ENERGY SOURCES

### *Oil Shale*

Although its presence as a potential energy source has been known since the 1860s, oil shale is among those resources now being extensively surveyed for high productive enterprises in the energy industry. It is the second most abundant source of energy in the US following only coal. Large deposits of oil shale exist in the Green River area of Colorado, Utah, and Wyoming, and also in Brazil, and are estimated to total some 26,000 billion barrels of crude oil potential (5:29). The amount in the Green River area is much greater than that in the entire Middle East oil fields (6:14). Extracting oil from oil shale is extremely expensive and could involve destructive strip-mining, and leave horrendous piles of debris, ruining thousands of square miles of landscape (7:655). However, the oil produced from shale is not price competitive, even after making generous allowances for restoring the land to something like its present condition.

Oil shale is usually taken from mountainous areas either by strip-mining or by use of the "room-and-pillar" method. The former is done in a similar manner to that used as exercised for strip-mining coal; the latter method involves the use of cavern excavations leaving columns of rock to support the roof. The shale, a very hard rock, is crushed and then heated to 900°F, using it to give off a vaporized product called kerogen. The kerogen is then condensed into a low-sulfur crude oil. About 30 gallons of oil can be produced per ton of oil shale (6:14).

The environmental aspects of oil shale extraction and refining are significant, and in some ways possess an enormous impact. The fine grit remaining from the vaporizing process poses a major disposal problem. The overall bulk of the residue exceeds the volume of the basic oil by 15%, and will not fit back into the hole from which it came. There is, therefore, a resulting pile of spend shale residue requiring either permanent above ground storage or disposal areas such as old mine shafts, fillable canyons, or pits. The high salt content in the grit must also be contended with to prevent pollution of local water supplies. Restoration of the strip mined areas required extensive plannning and costs also. A further problem, environmentally, is presented by the need for and the eventual disposal of large amounts of water used in the purification process and needed in areas already considered arrid.

Although problems are quite apparent, high interest in going after the oil in shale is developing. Considering all costs, including those involved in correcting any environmental ill effects, output of crude oil from shale could go as high as 11% of the total US consumption by the early 1980s. The original investment and operating costs of the production facilities could be amortized by that time (6:14).

### *Tar Sands*

Tar sands are oil-soaked sands that have to date been located in large amounts in only two areas in the Western Hemisphere: along the Athabasca River, in northern Alberta, Canada; and along the Orinoco River in Venezuela. This material found near the surface of the earth in these two places holds as much petroleum as all known conventional reserves (3:818). The time of significant production of crude oil from tar sands remains decades and billions of dollars in the future, due to the lack of worldwide exploration and the tremendous expense of extraction. No world inventory exists, yet the smaller amounts found in Utah would support the total United States energy consumption requirements for approximately two years.

Extraction is usually done by huge rotating bucketwheel excavators. The stocky sands are treated by a hot water floatation process in which the crude is removed by hot water and steam, at the rate of one barrel of crude oil per one ton of sand. The environmental problems posed include the disposal of the "tailings" residue, the reclamation of the land after mining, and the control of the refining stack emissions into the atmosphere (8:82).

### *Solar Energy*

Of the three principle (renewable energy sources," solar, geothermal, and fusion, the former is the most abundant and perhaps the most practical energy source for short-term and long-term research and development. For any particular period the sun pours onto the earth

100,000 times more energy than the world can electrically generate using its total current generating capacity (9:6). Solar energy could fill every nation's need for energy indefinitely to the future, with an equivalent heat potential of over 700 X $10^{18}$ Btu's in one year (the world currently uses .2 X $10^{18}$ Btu's per year) (5:37).

Replacement of present electric power sources with solar energy will be extremely difficult to accomplish due to the dilute nature of the sunlight's incidence, since it is subject to cloud cover changes, intermittent due to the day-night occurrence, and varies due to geographic location. To combat these problems, a variety of solar ray collectors are required each of which must have a high efficiency or collective ability. However, the advantages of this power source are manifested--inexhaustible supply, as noted; occurrence in vast amounts; universal distribution; freedom from fuel cost; and, significantly, relative freedom from environmental damage.

Solar energy has already been used for specific functions: recovery of salt from brine, water heating, drying of food products, high temperature research, use in home cookers, and as a source of electric power for satellites and space vehicles.

There are three basic methods of using solar energy. The first is by conversion to electricity, either directly through the use of solar cells situated on earth or mounted on space stations, or by heat engines involving thermal collectors and ocean "temperature difference" collectors. The second method is to use the solar energy to heat water, which in turn can be used for heating and cooling buildings. The final method is by producing clean renewable fuels by growing fuel-producing plants and by bioconversion to hydrogen or methane (5:165). Each of these methods are described below.

The direct conversion method uses photovoltaic devices, similar to those silicon type cells used in the space program, which have proven very dependable, durable, and pollution free in the production of electricity. The cost for these cells is very high. Even if mass produced, they would possibly cost thousands of dollars each. Space situated photovoltaic cells would avoid the variability of solar energy but would add the tremendous problem of energy transmittal to the earth. This again would mean greater cost. The use of microwave beams to transmit electrical energy from the collectors in space is feasible; however, the effect on safety and environmental considerations is unknown.

Direct conversion by heat engines involves the use of the sun's heat to produce steam or other vapors that could then be used in conventional or advanced power cycle turbines. In this method the temperature of the working fluid is elevated by a focusing mechanism. The energy produced is then transferred to another fluid in the form of heat, and is stored for use.

Heat engines could also be of use in developing energy from the temperature gradient found between the upper and lower levels of the ocean. The heat is extracted from the warm waters in the upper levels of the ocean by evaporating a fluid with a suitable boiling temperature. The resulting vapor is passed through the turbine where electricity is generated, and then is condensed by the cold water from the lower levels.

The heating and cooling of buildings, already being accomplished in certain areas as a supplement to conventional methods, is a use of the sun's power which appears simpler than the generation of electricity. Collectors, in large or small arrays, in fields or on rooftops, would operate on a principle similar to that of thermal electric generation. However, the cost and the complexity of construction is considerably less. Practical use of this technique in individual housing units is well within reach in the near future, for heating the house and for producing hot water. For cooling, further technology and cost reduction efforts are necessary.

Storing solar energy by growing plants is a conversion process in which the plants are grown, stored, and then burned in place of fossil fuels. They may also be converted by various treatments into clean fuels such as methyl alcohol, paraffin, oils, or carbon. Direct conversion to hydrogen by photosynthesis may also be possible.

Solar power seems to be the favorite for near-term development. It's not only dependable, with a vast resource base, but it poses no pollution problem. It further provides the source of the atmospheric winds, another means for generating electricity by the use of giant windmills.

*Geothermal Energy*

This seemingly limitless energy source, the heat in the earth beneath our feet, is proclaimed by most experts in energy to be the lowest cost potential source for producing electricity. In addition to being comparatively cheap, it is generally considered to be a clean and pollution free energy source. Dr. Robert Rex of the University of California firmly believes that geothermal heat power can be developed at less cost and in an earlier time frame than nuclear power. He has further stated that the entire state of California could meet all of its electrical power needs by the use of geothermal power sources only (7:677). Natural geothermal steam is used to generate electricity at the Geysers, north of San Francisco, in New Zealand, and in Iceland. The famed Larderello steam field plant in Italy has been in operation since 1913.

There are three basic categories of geothermal deposits, all of which occur naturally:

1. *Geopressure brine systems*—consist of highly porous sands saturated with salt brines at high temperatures and pressures.

2. *Hot dry rock systems*—consist of impermeable rock which lies above a local heat source such as a hot magma chamber.

3. *Hot spot systems*—which are of two types:

a. The vapor-dominated or dry system, which is usually referred to as the steam system; and

b. The liquid-dominated or hot water system. The heat from these two systems comes from some near-surface heat source upon which surface or near-surface water percolates, becomes superheated and rises to the surface as hot springs or as geysers of some sort (5:157).

Considerably more research is required before geopressure systems which do not exit naturally to the earth's surface can be tapped effectively to provide energy, although the brine component of most pressure systems presents less of a technical problem with which to deal. The high pressure, the high temperature, and the dissolved methane complicate the recovery operation.

The handling of the brine solutions presents a complex disposal problem, once the heat has been transferred from it to a second working fluid by way of heat ex-

changers. The development of corrosive-preventative fluids throughout the brine handling systems is critical, especially in the transport pipes, the pumps, and the heat exchangers. A need exists for a type of surface coating which will prevent adhesion of scale.

The hot dry rock systems, believed to have by far the greatest heat and energy potential for use over periods extending well into centuries, require the technical skills of oil drilling for extracting its energy. The most popular proposal involves drilling two wells thousands of feet down into the hot rock, injecting water into the one well, where it becomes superheated water or steam, and withdrawing it through the second well. Electricity is generated directly by turbines or indirectly through isobutane heat exchangers. No particular environmental problem results because the system is closed; however, rock contraction or thermal cracking of subsurface rock might produce serious surface effects.

Hot spot systems, mostly in the form of hot water systems, are essentially the most accessible for geothermal energy. Although tapping by drilling is often required, the distances to the hot water areas are generally less for the other systems. The injection and withdrawal operation is combined within a closed system similar to the hot dry rock system, except that the withdrawal phase occurs first, while the withdrawn water is reinjected after the heat has been removed. In this operation noxious fumes often escape and must be prevented from contaminating the atmosphere.

Various fundamental items of research are still needed before better use of geothermal energy can be promoted. These involve finding better methods of identifying the locations of the resources, developing more sophisticated geophysical techniques, and exploring for geothermal indicators. Other items of research needed include work on reservoir analysis, development, and management, and also more intensive study of ground water movements in the vicinity of magma masses. Greater knowledge of geothermal aquifiers and more extensive measurement data on heat flow phenomena through the varieties of hot rock formations are also needed.

## OTHER ENERGY SOURCES

### *Fuel Cells*

The fuel cell is an energy source which has been under study for over two decades and which is becoming a feasible item for renewed research. This device generates electricity when certain simple gases such as hydrogen and oxygen, or a simple liquid fuel like methanol, are fed continuously into the cell. It is composed of metal electrodes and plates made of carbonates which combine the constituents into water and electricity. This power-generating system produces little pollution, little noise, and appears very practical for small volume requirements such as mobile homes, boats, and automobiles. It may be feasible to design fuel cells sized for single unit home packets designed to provide power for the total home needs (7:675).

### *Coal Synthetics*

The production of synthetic "natural" gas (syngas), and synthetic crude oil (syncrude) from coal are new energy processes under study, with probable commercial enterprises in this area in the 1980s. It is estimated that by proper processing, a tone of coal would produce two to three times as much synthetic fuels as a ton of oil shale. Research in these areas is lagging; however, stronger interest is being developed because of European successes in this field and due to the abundance of coal reserves in this country. The environmental effects would be similar to those currently experienced in mining coal.

### *Magnetohydrodynamics (MHD )*

This energy system is one of the more unique types of advanced power cycle plants, plants which are designed to attain improved generating efficiency by using greater amounts of normally wasted heat. The MHD system substitutes a hot, flowing ionized gas for the rotating copper coils in an electrical generator. Such systems are estimated as being capable of extracting 60% of the available energy from the fuel source, one and one half times the efficiency of a conventional fossil-fueled power plant (7:675). In one proposed MHD generator, powder coal burns fiercely in a chamber. Combustion gases are squirted in a stream through a nozzle at supersonic speeds between magnets, resulting in an electric current which is captured by electrodes. Environmental impacts resulting from MHD power plants have not been adequately explored, and therefore, cannot be logically assessed.

### *Tides*

To harness energy from the ocean tides, huge underwater, submarine-like turbine generators are used. These turbines have reversible propellers and can churn out power as much as 240,000 kilowatts, as accomplished at the world's first large scale tidal power plant on the Rance River in Brittany (7:675). Cost of operation is extremely high. Canada and the United States are jointly surveying possibilities of tidal power plants in various parts of the Bay of Fundy, where surging tides of 50 feet are often experienced. No environmental effects of tidal power are currently anticipated.

### *Burning Trash*

This energy source amounts to a productive use of our domestic and industrial garbage waste. It is a way of solving solid waste disposal problems in that the ordinary trash and garbage wastes are burned and help produce electric power. The United States puts out a grand total of two and one half billion tons of waste per year - five pounds of garbage per person daily, and 60 pounds of agricultural waste per person per day in the form of manure and vegetation (7:673). If these amounts were burned in power plants, more than half the electricity we are now consuming could be produced. Since 1972, St. Louis has been burning shredded trash with pulverized coal to make electricity. Over one-fifth of the city's refuse is being converted each day into 300 tons of odorless, clean-burning fuel, a process which saves a ton of coal for every two tons of trash burned (7:673).

### *Superbatteries*

In a sense the storage of electrical power equates to a power source. To effectively use the energy generated from many energy sources, especially from solar energy, we need superbatteries to store the great amounts of energy not needed at the time of actual generation. These huge devices or facilities are necessary to store the sun's energy for use as electricity at night, or to store energy that power plants produce in low-demand periods

for later use when the demand for electricity is high.

One method of storing electricity is the "pumped storage" method, in which water is pumped from a lower level reservoir to a higher one using electricity produced from fossil fuel, nuclear, or solar power. At time of need the movement of the water to a lower level generates electricity hydroelectrically to meet the need. The efficiency of such a storage system is about 66%, since it takes about three kilowatt hours to pump the water to the higher level while the power generated hydroelectrically is about two kilowatt hours (7:171). One of these systems, in operation on the eastern shore of Lake Michigan, is able to generate 1.9 million kilowatts of electric power at peak-power periods as the water rushes down from the one-by-two-mile reservoir to the lake.

No other large-scale commercial storage methods exist. Electric storage batteries are prohibitively expensive for this purpose. Possibilities exist in the use of some sort of compressed air storage, or even space situated photovoltaic storage cells; however, technological data on either of these is sparse and a great deal of research effort would be required.

Of course, to follow this problem is another which is also receiving considerable study. This problem involves the movement of energy from its place of storage to the place of need. Heavy underground, nitrogen cooled cables may be the answer on earth, while microwave transmission may be the means from space storage.

## ENVIRONMENTAL IMPACT

The basic areas of concern regarding pollution produced as a by-product of the production of the power using the various alternate sources of energy discussed include reclamation of land disturbed by strip mining of coal and oil shale, loss of land areas due to facilities siting, acid mine drainage from both strip and underground coal mining and the leaching of waste piles from strip mining and oil shale processing, thermal pollution from electricity generation, disposal of brine, silting of streams from drainage of unreclaimed strip lands, particulates from various combustion processes, solid wastes from mining and processing, restricted use of large tracts of land needed for solar energy collection, and voids in the earth due to geothermal heat extraction. These, and combinations thereof, are to have an effect upon our environmental assessment of any full fledged operation of some or all of these energy generation systems. According to the Atomic Energy Commission, the items under current study in concert with new energy development include dry cooling tower technology, prediction techniques for water temperatures of bodies of water adjacent to or surrounding possible plant locations, development of means to alleviate thermal effects, determination of the effects of siting a number of power plants near large and populous ringed bodies of water like the Chesapeake Bay, and determination of biological effects of sudden temperature changes in water systems (4:121). Further studies of possible environmental effects deal with predicting and assessing the amount, behavior, and effects of heat discharged to the aquatic environment. The Ecology Effects Research Area is concerned with determining the limiting and optimum temperatures and oxygen concentrations for a variety of aquatic species in their different life stages, the study of ecological perturbations caused by waste heat, the study of effects of power plant discharge into the air on atmospheric mixing and motion, and of plume rise and dispersion of pollutants in the atmosphere (5:89). Resolving energy shortages, a problem which we could be easily confronted with at any time, is complicated by the problem of pollution, a problem most probably associated with power plants - corrosive gases, waste heat dumped into waterways, and stack emmissions - foul the atmosphere (7:654).

## CONCLUSION

As mentioned earlier, we are short of neither energy sources nor the technology to harness "new" power sources. Yet our country tends to lag in its efforts to offset the energy problem until the situation becomes really awkward, as it did in 1973 when we experienced, and suffered from, an "energy crisis." Yet the intent of this study is not to point the finger at any particular agency nor at our society in general, we Americans have accomplished that task without the author's need to accentuate; however, this study in alternate energy sources is intended to more positively identify promising areas for all those interested in promoting continued progress and productivity of our society. Hopefully, this study showed that energy sources for doing the things we want and need to do as a society are available, and the technology largely exists to make use of these sources. With proper forethought, the environmental impact of using these power sources can be controlled and perhaps even turned to the benefit of society.

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# CHAPTER VI — ENVIRONMENTAL LAW

## LAW & POLICY

By Ronald O. Graf, Maj. USAF

Federal legislation in the United States concerned with protecting our environment is a recent occurrence. Throughout the history of the United States, the pollution of our environment has been accepted for the most part as a necessary spin-off of technological advancement. It was not until the 1960s that congressional efforts began in earnest to face the problems outlined by such harbingers of doom as Rachel Carson, Barry Commoner, and Paul Ehrlich.

### *Early Beginnings*

Water was recognized by the early colonists as a commodity in need of protection. In 1647, the Massachusetts Colony passed a regulation preventing the pollution of Boston Harbor while in 1729, the South Carolina legislature passed a law which prohibited pollution which might be harmful to fish. These early attempts at pollution control were hampered by the lack of technology and an understanding of the environment, and an inability to cope with the problems of epidemic disease. These conditions led to the formation of numerous state boards of health—the first of which was formed in Massachusetts in 1869.

Throughout the early development of the United States, these attempts at legislation for the protection of the environment were localized and for the most part ineffective in controlling pollution. The first bills of major importance related to the environment to be enacted by the Federal Government were the Harbor Refuse Act of 1886 and the Rivers and Harbors Act of 1899. The former was designed to prevent the deposit of any refuse matter in New York Harbor while the latter made it unlawful to deposit specified refuse matter in any navigable U.S. waterway. Neither of these pieces of legislation were directed at pollution control, but rather at preventing impediments to navigation. It was only in recent years that these acts have been interpreted by the courts to the benefit of environmentalists.

Prior to 1948, Federal legislation in the area of pollution control was fairly limited. In 1912 Congress passed the first direct law aimed at the problem of water pollution. The 1912 Public Health Service Act provided for the investigation of water borne diseases by the Public Health Service (2:11). By 1920, oil pollution had reached serious enough proportions to warrant the introduction of numerous anti-oil pollution bills in Congress. The 68th Congress finally enacted into law the Oil Pollution Act of 1924 which was limited to oil pollution of coastal, navigable waterways. By 1938, fifteen states had water pollution control laws on their books; in 1946, six additional states had similar legislation. Up until 1948, the legal basis for pollution control was found in this legislation developed by the individual states (2:15). It is interesting to note that in 1937 Congress did pass major water pollution control legislation which was subsequently vetoed by President Roosevelt.

In 1947, the Federal Government passed the Federal Insecticide, Fungicide, and Rodenticide Act of 1947. This act gave initial impetus to the control of pesticidal pollution.

### *Water Pollution Control Legislation*

In 1948, after numerous previous attempts at establishing a strong Federal pollution control program had failed, Congress enacted the Water Pollution Control Act of 1948. This act required the U.S. Public Health Service to develop comprehensive programs in cooperation with the states for the solution of water pollution problems. It also provided for small grants and loans to aid in the solution of sewage and waste treatment problems. This Act was extended by the 82d Congress until 1956.

The Federal Water Pollution Control Act of 1956 extended and strengthened the provisions of the 1948 Act. The 1956 Act established the Surgeon General of the Public Health Service as its administrator under the supervision of the Secretary of Health, Education, and Welfare (HEW). This act provided for the further study of pollution problems and for matching grants for local sewage disposal plants. The 1956 Act was never used to its full capacity, however, for President Eisenhower was opposed to Federal involvement in pollution abatement (6:4-34).

The 1969 Amendments to the Water Pollution Control Act authorized seven laboratories for water pollution studies and increased grants to states and municipalities. Between 1961 and 1965, it appeared that a major shift took place in either public opinion or the thinking of Congressional membership (2:31). The Water Quality Act of 1965 represents the first serious attempt by the Federal Government at a comprehensive water pollution control program. Water pollution control was taken out of the Public Health Service and placed under the newly created Federal Water Pollution Control Administration (FWPCA) initially under HEW and later under the Department of the Interior. The 1965 Act authorized increased financial assistance to states and cities for treatment plants and directed the states to develop water quality standards by June 30, 1967 and plans to meet them. This act was followed by the Clean Water Restoration Act of 1966 which again increased financial aid to states for water pollution control programs and strengthened the controls of the Oil Pollution Act of 1924.

In 1970 the Water Quality Act established more positive control measures for oil pollution, wastes from water craft, and other pollutants. The FWPCA became the Federal Water Quality Administration (FWQA) and in 1970, the FWQA was placed under the new Environmental Protection Agency (EPA). This act continued to maintain a basically weak Federal-State program of control of interstate waters with no meaningful enforcement program (6:4-35).

The Federal Water Pollution Control Act of 1972 authorized the largest amount of money yet for environmental protection—$24.6 billion for water pollution control over three years. Its goal is the elimination of pollution in U.S. waterways by 1985. The passage of this act emphasizes the degree of citizen concern for the environment as it was passed by the Congress over the veto of President Nixon.

In all of the previously discussed Water Pollution Control legislation, enforcement of the law was limited. For this reason, the Rivers and Harbors Act of 1899 has become the primary means for environmental litigation. In 1966, a court ruled that the Refuse Act of 1899 (sections 407, 411, and 413 of the Rivers and Harbors Act of 1899) made it illegal to discharge industrial pollutants into navigable waters without a permit. This requirement had always been part of the 1899 Act but up until May 1971 only 415 permits had been granted by the U.S. Army Corps of Engineers (7:4-118). In 1971 the Refuse Act Permit Program was developed to require a permit from all who discharged into navigable waterways. Permits would be granted if the discharge was not in violation of the Federal Water Pollution Control Act. Under the Refuse Act, many violators have been convicted including a penalty against one company for $125,000 (2:8).

*Air Pollution Control Legislation*

Although air pollution in the United States had become increasingly evident during the first half of the Twentieth Century, it was not until after such events such as the 1948 episode in Donora, Pennsylvania, and the 1952 episode in London that any positive action was taken by the Federal Government. In Donora, twenty persons died due to air pollution and a temperature inversion. In London, over a five-day period, over 4,000 deaths were attributed to an air pollution/thermal inversion combination.

Between 1950 and 1954, a number of unsuccessful air pollution control bills were introduced into Congress. It was not until 1955, however, that Congress passed the first Air Pollution Control Act. This act provided for research and grants but once again was hampered by President Eisenhower's opposition to Federal enforcement of pollution abatement.

In 1959, the 1955 Act was extended for four more years. A 1960 amendment to the 1955 Act directed the study of pollution resulting from motor vehicle exhausts as did a 1962 amendment. In 1963, the Clean Air Act was signed into law by President Johnson. Under the 1963 Act, at the request of the state, HEW could hold public hearings, then a conference, and finally request Federal Court action, if necessary, on the question of air pollution. This system proved unworkable as only one case was ever taken to court under the 1963 Act and none under a 1967 Clean Air Act which provided for the same type of enforcement system (6:3-27).

In 1965, the Motor Vehicle Air Pollution Control Act gave HEW authority to establish permissible emission levels for new motor vehicles. A 1966 amendment to the Clean Air Act authorized additional grants to air pollution control agencies. The Air Quality Act of 1967 required the HEW to establish air quality control regions in the United States and to issue air quality criteria for each region. States were then expected to develop and enforce standards for their regions. This act proved unworkable and tended to delay any serious air pollution legislation (6:3-32).

The Clean Air Act of 1970 established a firm statutory base for legal protection of the environment. The act established national air quality standards, emission standards for hazardous substances, and standards of performance. It provided for penalties of $25,000 per day for a knowing violation of the standards or imprisonment for one year, or both. For a second knowing violation the fine is $50,000 per day and/or imprisonment for two years. Section 304 of the act authorized citizens to bring suit against private individuals or the Government (except where protected by the 11th Amendment). The act consists of three parts—Title I—Air Pollution Prevention and Control, Title II—Emission Standards for Moving Sources, and Title III—Administration.

Section 303 of the Clean Air Act of 1970 gave the administrator of the EPA the authority to bring suit on behalf of the United States to abate pollution considered to be an imminent danger to health when State or local authorities have not acted. In 1971, this provision was used to close down the steel and other industries of Birmingham, Alabama for thirty-one hours (6:3-51).

Under the 1970 Clean Air Act, the EPA established 1975 as the date for state compliance with primary air quality standards to protect public health. Secondary standards were established to protect property and were targeted for compliance a "reasonable" time thereafter. Many states have used the 1975 date as their target for achieving both primary and secondary standards. However, the energy crisis threatens the achievement of both of these goals (3:68).

*Other Pollution Control Legislation*

Within the area of solid wastes, there are two major pieces of federal legislation recognizing the problems of disposal and pollution. The first is the Solid Waste Disposal Act of 1965 which was designed "to develop efficient means of disposing of the millions of tons of solid wastes that clog the nation's cities and countrysides [9]." However, the act was limited to providing technical and financial assistance to the States and to establishing a national program for research and development.

The second bill to be passed by Congress in the area of Solid Wastes was the Resource Recovery Act of 1970. The intention of this act was "to stimulate the development of resource recovery methods which will provide for more economic use of wastes [8]." This was to be accomplished in part by providing special grants for the investigation of energy and material recovery projects and for state and local planning and improvement of solid waste disposal facilities. Section 212 of the Act requires a report to Congress on National Disposal Sites and the solid wastes disposed of therein. Title II, section 202, of the Act established a National Materials Policy which recognized the limitations on natural resources and the need for efficient utilization of these resources.

Both the 1965 and 1970 Acts demonstrated an awareness by Congress and the American people of the solid waste problem while leaving the responsibility for collection and disposal of solid wastes with State and local authorities. The Solid Waste Disposal Act does not provide for any monitoring, control, enforcement, or penalties by Federal agencies (4:6-8).

The Noise Pollution and Abatement Act of 1970 was the first Federal legislation directed at the overall area of noise pollution. Under this Act, the EPA was required to establish an Office of Noise Abatement and Control to investigate and research environmental noise. The Act provided that Federal agencies or Federally supported activities producing objectionable noises as determined by the Administrator of the EPA must consider ways of abating the noise in consultation with the EPA.

It is of interest to note that the Department of Defense has considered the problems of noise pollution for a number of years prior to the 1970 Act. Military Standard (MIL-STD) 1472A sets objective limits on noise in areas where speech communication is necessary. MIL-STD 008806B, AFM 86-5 and AFR 55-34 set policies for reducing noise levels in aircraft cabin spaces and reducing noise levels on Air Force bases. MIL-N-83155A covers noise suppressors on engine test cells and AFM 160-25 covers environmental engineering, evaluation, and control of community noise. AFR 160-3 is designed to protect the hearing of personnel exposed to occupational noise.

Public concern for the dangers of radiation pollution has been with us since the end of World War II. In 1954, Congress passed the Atomic Energy Act of 1954 which provided for licensing of all commercial and industrial operations which used any of the special nuclear materials outlined in the Act. Penalties for violation of the Act were also prescribed ranging from $1,000 to life imprisonment.

In 1968, an amendment to the Public Health Service Act provided for the protection of the public health from radiation emissions from electronic products. This amendment is known as the Radiation Control for Health and Safety Act of 1968.

*National Environmental Policy Act*

On January 1, 1970, the National Environmental Policy Act (NEPA) (Public Law 91-190) became law. This Act created the Council on Environmental Quality (CEQ) and outlined a broad national policy for the protection of the environment. As stated in Section 2 of the Act,

> The purposes of this Act are: To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the nation; and to establish a Council on Environmental Quality (7:62).

Within the area of environmental protection, the NEPA is the most important piece of legislation enacted into law (1:v, 7:iii, 6:1-11). Its importance lies not in the basic wording of its provisions, but in the interpretation placed on these provisions by the United States courts and by Section 102(c) which requires the preparation of an environmental impact statement (EIS).

A basic question needing to be answered is whether or not the NEPA created an enforceable right to a healthful and aesthetically pleasing environment (6:1-12). Section 101(b) of the NEPA establishes the responsibility of the Federal Government for protecting the environment consistent with national policy so that the United States may—

> (1) fulfill the responsibilities of each generation as a trustee of the environment for succeeding generations;
> (2) assure for all Americans safe, healthful, productive and aesthetically and culturally pleasing surroundings;
> (3) obtain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;
> (4) preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity, and variety of individual choice;
> (5) achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities; and
> (6) enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources.

Interpretation of this section by the courts has not fully answered this basic question of third party rights.

In order for a plaintiff to carry on a law suit, the plaintiff must satisfy the court that he has or will suffer injury (injury-in-fact) and that the law or statute which the plaintiff wishes to invoke covers the zone of interests of the plaintiff (6:1-17). This is the question of the plaintiff's "standing."

An early court interpretation of the question of standing was found in the case of *Scenic Hudson Preservation Conference V. Federal Power Commission* (Scenic Hudson I). In this case a coalition of environmental organizations invoking the provisions of the NEPA sought to stop construction of new pump-storage facilities by Consolidated Edison in the vicinity of Storm King Mountain. In setting aside the FPC licensing order, the court held that the Scenic Hudson Preservation Conference did meet the requirements for standing. Subsequent court actions have somewhat modified the interpretations of standing.

A major court action involved the interpretation of Section 102(c) of the NEPA. As outlined in the NEPA, Section 102(c) might have been of little importance to environmentalists if the courts chose to conservatively interpret its provisions. However, a landmark decision in 1972 by the District of Columbia Circuit Court insured a more liberal interpretation. This decision involved the *Calvert Cliffs Coordinating Committee V. Atomic Energy Commission* case in which the committee contended that certain rules adopted by the AEC to govern consideration of environmental matters did not meet the rigor demanded by the NEPA (6:1-32). The court held that Section 102(c) was subject to a strict standard of compliance and that the AEC "must revise its rules governing consideration of environmental issues." This case has been accepted as "the definitive gloss on NEPA (1:247)."

The NEPA continues to be interpreted by the courts. To date, the courts have generally interpreted the NEPA to the benefit of environmentalists. As stated by the Court of Appeals for the District of Columbia, the provisions of the NEPA were not meant to serve as mere "paper tigers" (7:2). Recent Supreme Court findings during 1974 concerning class action suits again place the question of standing of environmental groups in doubt (5). Further court decisions will be necessary before this issue is resolved.

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# CHAPTER VI — ENVIRONMENTAL LAW

## AF & DOD ENVIRONMENTAL POLICY

By Joseph H. Cox, Jr, Capt, USAF

*Background.*

Public Law 91-190, otherwise known as the National Environmental Policy Act of 1969, was enacted 1 January 1970. This law usherd in a new era of environmental policy for the Department of Defense (DoD) and the Air Force, as well as nearly all other agencies of the Federal Government. From the National Environmental Policy Act, there followed a series of Executive Orders, DoD Directives and Instructions, and Air Force Regulations (ARF) to present and explain the duties and responsibilities of various component units. Currently, the primary vehicles of policy are Public Law 91-190, Executive Order 11752, DoD Directives 5100.50 and 6050.1, AFR 19-1, and AFR 19-2. Pages 12 and 13 of AFR 19-1 offer a more extensive list of the documents related to the Federal Government's environmental policy. Due to the constantly changing nature of the environmental program, it would be wise to consult this list from time to time for an update of the current documents. In addition, each major command must maintain a supplement to AFR 19-1 (9:6).

### GENERAL DoD/AF POLICY

> Recognizing that various Department of Defense activities, programs and technological advances have an impact on the environment; Department of Defense components shall (1) comply with the spirit as well as the letter of the National Environmental Policy Act and all other Federal environmental laws, executive orders, and regulations, and (2) demonstrate leadership in environmental pollution abatement and enhancement of the environment in a manner consistent with the security interests of the nation (2:2).

The above statement of DoD Directive 5100.50 is repreated, with amplification, in AFR 19-1. In particular, this section of AFR 19-1 goes into slightly more detail than the DoD Directive with regard to the methods to be used and names a number of additional source documents for direction in certain program areas. The following section of this paper will explore some of these points in relation to the provisions of the "specific policy" sections of the DoD Directives and Air Force Regulations.

### SPECIFIC POLICIES

This section will present specific policy areas covered in the source documents. Wherever possible, examples will be given in an attempt to relate policy statements to actual accomplishments.

*Demonstration of Leadership*

Executive Order 11752 and the DoD Directives and Air Force Regulations which follow from it clearly state as a major policy the idea that Federal agencies will provide leadership in ". . . preventing, controlling, and abating environmental pollution (9:2)." The two primary avenues by which this policy is to be implemented are support of area pollution abatement programs of local communities and by accelerating corrective measures to meet established standards and criteria at local installations (2:2; 3:2; 9:2).

*Compliance with Standards*

It is Air Force policy to comply with not only Air Force directives, but also with both the spirit and letter of the National Environmental Policy Act and all other Federal environmental laws, Executive Orders, regulations, and directives. In addition, criteria and standards of the Environmental Protection Agency and the intent of state and local pollution abatement laws, regulations, criteria, and standards apply to Air Force operations (9:2). In the case of an Air Force installation in a foreign country, AFR 19-1 requires operation of facilities so as to comply with the generally applicable environmental standards of the host country and the requirements of Status of Forces Agreements.

*Allowable Exemptions from Compliance with Standards*

There are four important exceptions to the policy of compliance presented in the previous section of this paper.

First, DoD Directive 6050.1 exempts "multi-national actions in which the DoD is not the primary decision-making authority." An example of such an action might be the establishment of an air-to-ground weapons range by the North Atlantic Treaty Organization (NATO). Although the DoD and the Air Force would be involved through their participation in NATO activities and would be required to file assessments of environmental impact and comply with Federal environmental regulations if a range were proposed in the United States, the fact that the primary decision-making authority was outside DoD would relieve DoD and the Air Force from responsiblility to comply with Federal environmental requirements.

A second improtant exception is in the case of "combat or combat-related activities in a combat zone (3:1)." Thus, the policy statements recognize the fact that the primary mission of the Air Force is to "fly and fight" and that, while environmental protection is a very important consideration, any conflict between national security and environmental protection must be resolved in favor of security.

A third exception allowed under DoD Directive 6050.1 is for "other emergency activities". AFR 19-1 goes into more detail in the mechanics of such an exemption:

> Make all practical efforts to obtain presidential exemption for certain facilities from complying with environmental control standards when in the paramount interest of the nation. To exempt the facility, the installation must apply for a waiver through command channels to HQ USAF/PREV, Wash DC 20330. Send an information copy of the request to HQ USAF/SGP, and when Industrial Production Facilities are involved, RDPI. The application must justify the waiver (9:2).

The final area of allowable exception is to the requirement to comply with state and local standards, laws, and regulations. Section 1 of Executive Order 11752 states, in part:

> In light of the principle of Federal supremacy embodied in the Constitution, this order is not intended, nor should it be interpreted, to require Federal facilities to comply with State or local administrative procedures with respect to pollution abatement and control.

On June 5, 1973, the U.S. Court of Appeals for the Sixth Circuit rule in *Commonwealth of Kentucky v. Ruckelshaus*, No. 73-2099 that Federal facilities are not required by the Clean Air Act to obtain local permits. Although required to comply with substantive requirements and to provide an exchange of information with state and local governments, the Court held that obtaining permits was an administrative regulation and not binding upon Federal agencies. AFR 19-1 reiterates this point:

> Air Force installations or activities are not required to apply for state or local air and water pollution control permits or licenses for the construction or operation of facilities, including certification of operators, nor are they required to register facilities or operations if the registration process, in effect, is a permit application that would lead to the discretionary issuance or denial of a permit or license. Register Air Force activities only to the extent necessary to advise state and local authorities of the scope of Air Force activities (9:3).

*Environmental Assessments and Statements*

Although a full treatment of the subject of environmental assessments and statements is beyond the scope of this paper, it is worth mentioning that AFR 19-2 provides guidance as to when such documents are required and what procedures are to be followed in their preparation. AFR 19-1 requires assessment of "the environmental consequences of any proposed action in accordance with AFR 19-2 at the earliest practicable state in the planning process and in all instances before decision (9:2)." An environmental assessment serves to indicate areas that need more detailed study or that no additional reviews are necessary. A formal environmental assessment will be prepared for actions that "have or could have an environmental impact, involve or are likely to create public controversy, or are a line item in the annual budget (10:1).

An environmental statement is a formal document which describes the environmental impact and possible alternatives of a proposed action. Environmental assessments and statements and the processes surrounding them are designed to accomplish several things. First, the requirement to prepare these documents insures the consideration of the environmental impact of a proposed action before the final decision is made. Second, the procedures force the consideration of alternative courses of action in the light of their relative benefits and costs, including the detrimental effects on the environment, if any. Third, the processes are so structured that objections may be aired by interested parties before the final decision to commit funds is made. This will reduce the chance of wasting scarce funds on projects which may be closed down later because of their harmful effects on the environment.

Interested readers are referred to reference 7 for an example of the use of the environmental statement procedure and contact with local agencies to ascertain the implications of a proposed course of action.

*Compliance with the Freedom of Information Act*

AFR 19-1 reiterates Air Force policy stated elsewhere in regard to the release of information to the public as required by the Freedom of Information Act and Office of Management and Budget Circular A-95. Basically, information and advance must be provided to individuals and agencies who seek to improve environmental quality. The provisions of AFR 12-30 and AFR 190-12 apply and will afford guidance with regard to classified and privileged information (9:2).

*Compliance with the Occupational Safety and Health Act*

AFR 19-1 requires, in addition to environmental quality requirements, that, when appropriate, the requirements of the Occupational Safety and Health Act, Executive Order 11612, and AFR 127-12 receive full consideration (9:2).

*Cooperation with Outside Agencies and Individuals*

A very large proportion of the body of policy under discussion deals with cooperation with agencies and individuals outside the Air Force. In the case of AFR 19-1, approximately 40% of the section dealing with policy concerns some sort of cooperation or interaction with state or local agencies or interested individuals. In addition to the requirements of the Freedom of Information Act, there are requirements to consider both favorable and unfavorable comments of experts, concerned public and private organizations, and citizens, insure that contracts for waste disposal require the disposal method to be in accordance with local, state, and Federal standards, use municipal or regional waste collection and disposal systems whenever possible, and require operators of Air Force pollution control facilities to meet the same levels of proficiency as the operator certification standards of the state in which the facility is located. Facilities must cooperate with state and local environmental agencies and provide data relevant to determination of compliance with standards or emission limitations, except as covered in the previous discussion of Federal immunity from administrative requirements of state and local governments. It is also part of stated policy to cooperate in community environmental action programs (9:2-3). In many cases, there have been very successful programs initiated with local agencies to coordinate land use zoning, traffic problem study, and similar programs. One such program exists in the Randolph AFB area (4), and another excellent article on the coordination of land use planning or Air Installation Compatible Use Zoning (AICUZ) may be found in reference 11. Basically, these programs consist of the formation of special bodies with representation from the base and the surrounding communities. The special panels attempt to solve problems common to the base and its neighbors, such as discouraging the residential development of high noise and crash hazard zones. Another excellent article which discusses the inpact of the public on the decision making process appeared in the February 1975 issue of *Air Force Civil Engineer* (8). This article points out the fact that, assuming a project is worthwhile and well designed, the public can usually

be counted upon for support once the project and its need are explained. It makes good sense to keep the public (who, after all, pay our bills) informed and enlist their support for important programs.

*Pollution Control and Design of Facilities*

FR 19-1 requires the inclusion of control measures for environmental pollution in designs for "new Air Force buildings, facilities, weapon systems, operations, tests, exercises, procedures, and projects for rehabilitation or modification of structures (9:2)." The best answer to the environmental problems with which we are all faced is proper planning to prevent the establishment of a source of pollution woes. Measures taken in the planning and original decision making process are both more effective and less expensive than those measures taken at a later time to try to control or solve an existing problem; therefore, preventive measures are preferable to corrective measures taken after the fact.

*Preventive Measures*

There are three types of preventive measures discussed in AFR 19-1 which are to be used to affect pollution control.

*Reduction or elimination of waste at the point of generation.*

Obviously, the reduction or elimination of waste at the point of generation can go a long way toward cleaning up the environment. If the amount of waste produced is significantly reduced, the problem of disposal will reduce in scope, the harmful effects or landfills and sewer effluent on the environment will be reduced, and the scope and cost of the entire problem will be less than when larger amounts of waste are produced.

*Selection of materials.* When selection chemical compounds and materials to be used in Air Force projects, future environmental problems may be avoided or lessened by inclusion of environmental considerations among the factors in the decision. For instance, careful choice of laundry compounds to be used at the base laundry may significantly reduce the treatment problems and operation expenses at the sewage treatment facility.

*Inclusion as an element in specifications.* This preventive measure is, of course, related to several of the others which have been discussed in this paper; however, it is worthwhile to mention it again in the specific context of specifications. All of the good planning and material or process selection in the world will not do any good at all toward solving or preventing pollution problems unless the proper decisions, once made, are properly reflected in the specifications by which the project is accomplished. In the final assessment, it is the specificiations which drive and determine the final result of any undertaking--especially one which is accomplished by contract. If proper measures are designed into a facility but left out in the construction phase because of faulty specifications, the end result is no different than it would be if the environmental considerations had been ignored in the planning phase. If this happens, the base will be faced with another case of having to cure an existing pollution problem, possibly by a method more expensive and less effective than that originally planned for inclusion in the facility.

*Disposal or Discharge of Pollutants*

Another of the main points covered by the documents providing guidance in the environmental field is the disposal and discharge of pollutants. AFR 19-1 provides something of a general policy statement in this area:

> Dispose of or discharge pollutants in a manner that will not:
>
> (a) expose people to concentrations of any agent (chemical, physical, or biological) hazardous to health.
>
> (b) alter the natural environment so that an adverse effect is created with respect to human health or the quality of life.
>
> (c) result in substantial harm to domestic animals, fish, shellfish, and wildlife.
>
> (d) cause economic loss through damage to plants or crops.
>
> (e) impair recreational opportunity and natural beauty or cause ground water contamination.

Further guidance is also contained in AFR 19-1. It states that Air Force activities must insure that all contracts for disposal of waste require the disposal method to be in accordance with all local, state, and Federal criteria and standards. The activity must also verify that the contractor complies with these provisions of the contract.

Another paragraph of AFR 19-1 establishes as policy the preferential use of municipal or regional waste collection and disposal systems. If such facilities and systems are not available to the Air Force activity, the activity must do whatever is necessary to properly dispose of the waste, including:

> (a) When appropriate, install and operate waste treatment and disposal facilities.
>
> (b) Provide trained manpower, laboratories, and other supporting facilities as appropriate to meet the requirements of issued standards.
>
> (c) Require operators of Air Force pollution-control facilities to meet levels of proficiency consistent with the operator certification requirements of the State in which the facility is located (9:3).

Such Air Force operated facilities will cooperate with the local and state authorities, but remember that the Air Force is not required to apply for or obtain licenses for either facilities or operators.

Another point which is receiving much attention in Air Force and DoD circles is the use of reprocessing, recycling, and reuse of waste materials. AFR 19-1 states that Air Force activities will "avoid or minimize the creation of wastes throughout the complete cycle of operations . . . and, to the extent practicable, dispose of the wastes that are created by reprocessing, recycling, and reuse." The area of recycling and similar activities is beyond the scope of this paper; however, there have been some successful experiments with recycling in the Air Force. One such experiment worth study for ideas which might be adapted to situations at other bases was conducted at Carswell AFB and reported in the March 1973 issue of *Airman* (1).

*Storage and Handling of Potential Pollutants*

Although occurrences are rare when compared with many other causes of environmental pollution, inadvertent spills of petroleum products and similar liquid

pollutants receive much publicity whenever they occur and are often a source of expensive litigation and penalities. In addition, cleanup costs often run very high and a long period of hard work to improve relations with the local public may go down the drain with the oil. For these reasons, every precaution must be taken in the storage and handling of potential pollutants. AFR 19-1 requires that such materials be stored and handled in accordance with all local, state, and Federal standards and that engineering safeguards such as dikes and catchment areas be provided when necessary to prevent the pollution of water by accidental discharge of stored fuels, oils, solvents, and other chemicals (9:3). Air Force personnel should also be aware that contracting services such as storage and handling of fuels does not remove the risk of penalties in the event of a spill. The 14 June 1974 issue of *The Environmental Reporter* contained a report of an oil spill in Maine caused by a contractor. In this case, both the contractor and the Air Force were sued by the State of Maine for damages. The contractor was charged with using improper procedures, but the Air Force was blamed for failure to properly clean up the spill. Another aspect of this type of problem which deserves some thought is the fact that every moment counts in the event of an oil or chemical spill into water. Fund obligation authority and equipment must be obtained quickly because the problem will continue to compound itself until the spill is cleaned up. Also, effects to marine organisms, birds, and other forms of life may continue for some time after the immediate problem of the polluting substance is removed. In the case of the above mentioned oil spill in Maine, the state attorney general estimated in his suit that damage at the time of the suit was $10 million and that another $10 million in damages would occur before corrective action could have any effect.

### *Handling of Radioactivity*

Air Force policy is to assure that discharges of radioactivity conform with applicable rules of the Atomic Energy Commission (now the Energy Research and Development Administration) and the Environmental Protection Agency. Specific guidance in this area may be found in AFR 160-132 and the 11ON Technical Order series (9:3).

### *Land Management*

Many Air Force bases are custodians for the Federal Government and the poeple of large areas of land and water, much of it in a natural or near-natural state. DoD and the Air Force require that facilities "conduct an integrated multiple-use natural resources land-management program (9:3). This program will vary from base to base, but would include such elements as forest and woodlands, fish and wildlife, water resources, open space, vegetation, recreation areas, increased public use, and nonconsumptive uses of lands under Air Force control. More specific guidance in this area may be found in AFR 91-26 and AFM 126-1. A number of bases have extensive programs in this area, among them Eglin AFB, Barsdale AFB, and Elmendorf AFB.

The Air Force also requires its installations to "protect wetlands from encroachment, filling, dumping, siltation, erosion, or other disturbance of their natural condition in accordance with applicable state and Federal statues (9:3)."

### *Historic and Cultural Sites*

In a few cases, Air Force installations may lie on lands of historic, cultural, paleontological, or archaeological significance or may have structures or objects of such significance within their boundaries. In such a case, the Air Force requires that such resources be preserved, protected, and restored (9:3).

### *Priorities*

From time to time, the problem of availability of funds or other resources may force a decision to postpone the accomplishment of one or more environmental protection projects. If this becomes necessary, priority will be given in the following order:

(a) Situations that constitute a hazard to the health or safety of man.

(b) Situations that are cost effective.

(c) Situations that affect the recreational and esthetic value of our natural resources (9:3).

## CONCLUSIONS

The DoD and the Air Froce have been tasked by the Congress and the President with the role of leadership in the field of environmental protection. Protection of the environment is a complex set of problems and solutions. Success can be acheived only through careful planning and consideration of all aspects of every decision followed by the inclusion of carefully designed specifications in each project. Special precautions must be taken and emergency procedures must be planned ahead of an actual accident such as an oil spill, contracts must be written to include environmental considerations and monitored to insure compliance, and all possible implications of an action must be considered before the action is taken.

If the fight to clean up our environment is to be won, it will be on the strength of good planning and consistent implementation of the plans by sincere, concerned personnel. This means, among other things, looking for a solid technical solution to a problem rather than looking for justification for variance from the standards or a loophole in the requirement to meet the standards.

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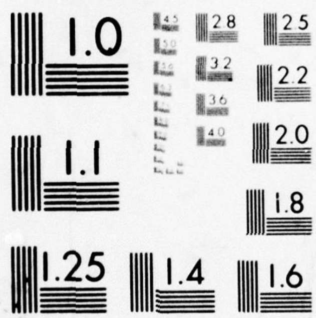

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# CHAPTER VI — ENVIRONMENTAL LAW

## LAND USE PLANNING

By Frederick S. Gersh, Maj, USAF

The previous chapters have covered each of the separate major issues involved in environmental planning and protection. The purpose of this chapter is to now show how these individual parts fit together. This is done through the creation of a plan. In the private sector this plan is referred to as the Comprehensive Plan and in the Air Force it is called the Installations' Comprehensive Plan. By combining each of the environmental issues into one formalized document the decision maker has ready access to all the factors that are essential for him or her to arrive at the best possible use for the land resources under consideration.

This chapter is divided into four parts: introduction and definition of comprehensive planning; background and land use controls; the planning process (i.e., the Air Force process in creating the Installations' Compreshensive Plan); and the major elements of this Comprehensive Plan. Because this book is directed toward Air Force military and civilian personnel, details regarding the Air Force's planning process are specifically addressed.

### INTRODUCTION AND DEFINITION OF COMPREHENSIVE PLANNING

Each of you probably has looked at a farmer's field of crops or a neighbor's or even your own vegetable or flower garden. Do you recall the exactness, the order and the even balance between one row and another, or one group of flowers with another? What you were observing was one small aspect of land-use planning. On the other side of this orderly scene is traffic congestion, streets without sidewalks, improper drainage, airport encroachment, and structures that sink--vivid examples where the planner or the approving authority did not consider all aspects involved with the land resource. All too often, the economic factors override the social, environmental, and even physical considerations and interrelationships of the planning process, and yet, without considering those aspects besides costs, the Air Force, for example, has been faced with ". . . the inability to proceed with construction contracts . . . mission degradation, . . . project scope reductions . . . and embarrassment (11:5)." In the words of Major Sims, *et al.*,

> The absence of effective planning strategies can result in serious impacts on the ability of the Air Force to perform its mission efficiently and on time (11:4).

To avoid any further changes and influences which would inpact the capability of an Air Force base and missile site to support their mission to fly and train, Air Force commanders, with the guidance from their Air Force Civil Engineers, undertook a program to develop both a "plan of action" and an implementation program. This action further emhanced the Air Force partnership with local communities and achieved common local and regional objectives with regard to the optimum use of scarce resources (6; 9). One professional land planner described land use planning in terms of site planning. Rubenstein says,

> Site planning is the art and science of arranging the uses of portions of land. The site planner designates these uses in detail by selecting and analyzing a site, forming a land-use plan, organizing vehicular and pedestrian circulation, developing a visual form and materials concept, readjusting the existing landform by design grading, providing proper drainage and finally developing the construction details necessary to carry out the project (10:1).

The above series of actions involves both an integration of the various parts of the project being considered and the adjacent environs (i.e., the total land environment system).

Dr. Rolf Eliassen of Stanford University has developed a graphic model that effectively illustrates the land environmental systems, Figure 1 (5:22). The reader should note the variety of requirements land is called upon to perform. It is this varied role that causes the land planner to constantly undergo a logical process of research, analysis, and synthesis to such questions as; "Where are you now? Where do you want to go? and How do you get there?" Just such questions are used when planning a trip, particularly to some place you have never gone before. You develop a plan using a road map. You integrate your mode of transportation, your schedule, the roadways to be traversed, and the various places and alternatives required for refueling and refreshment (1). So too, the answers to the same three questions have been asked in the Air Force relative to land usage. The result was the Air Force Installations' Comprehensive Plan, formerly named the Base Master Plan. The Master Plan previously ". . . focused on the physical layout and development of on-base facilities and services (14:1)," now the Plan incorporates interrelational analysis between ". . . natural and man-made environments; the social characteristics and needs of people; and the dependencies between air bases and surrounding communities (14:1)." This change came about with issuance of the Director of Civil Engineering, Brigadier General Thompson's letter, "1975 Comprehensive (Formerly Master) Plan Submittal," dated 14 April 1975. Thus a total integration of the planning, environmental protection, and public relations requirements into the "plan, build, and maintain" civil engineering responsibilities was to be the new planning objective. This "Plan" would result in minimizing duplication, increasing overall effectiveness by providing a comprehensive, consolidated plan, and insure compliance with existing and anticipated public laws (6; 13). A succinct definition of the Comprehensive Plan, then, is:

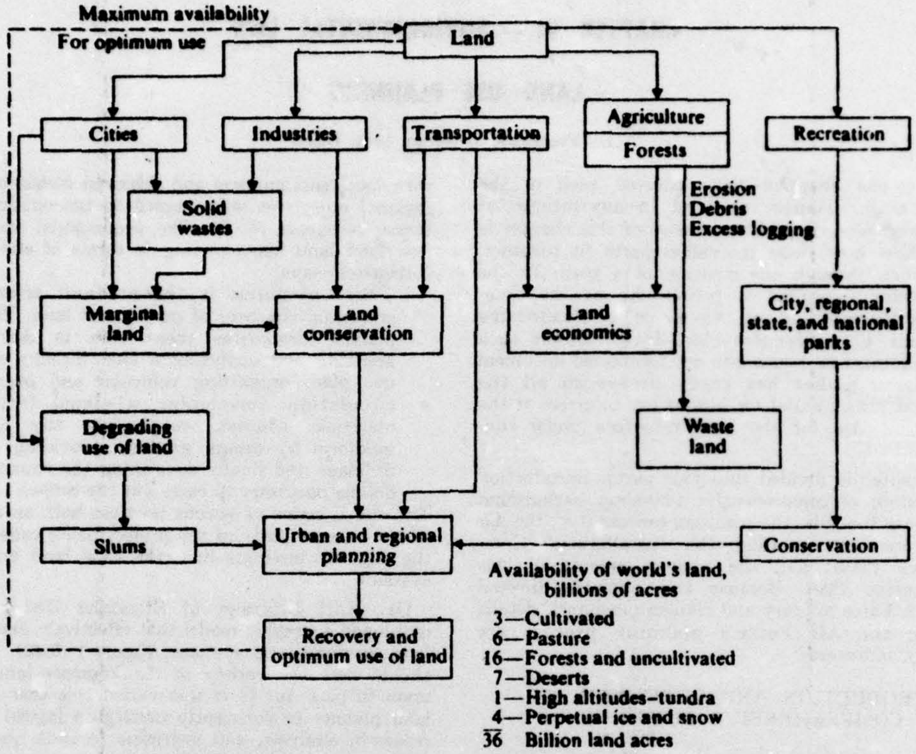


**Figure 1. The Environmental System of Land (5:22).**

> A comprehensive source document, which presents in graphic and narrative form, the existing composition of the base in its environs, and orderly (long range) development of the base and environs to ensure continued capability to perform the assigned mission (2).

Now that the reader has been provided with a general definition of the Comprehensive Plan, the next part of this chapter relates some of the background and land use control considerations that preceded the comprehensive planning program.

## BACKGROUND AND LAND-USE CONTROLS

### *Background*

In the late 1960s, the "Ecology Movement" reached a high degree of national interest. Various environmental interest groups pushed for Federal legislation regarding air and water pollution and airfield encroachment. Congress and the President reacted with various forms of legislation to protect the public (1; 11). One of the programs the Air Force originated, in early 1971, was involved with the protection of flying operations at each base. Urban encroachment was beginning to result in changes to an installation's flying mission. Communities adjacent to the bases were voicing objections to unacceptable noise levels and the potential aircraft accident hazard. Recognizing this public concern and the encroachment situation, the Air Force initiated the "Greenbelt" concept (12; 13; 15). The purpose of this initial land use compatibility program was to identify a rectangular area extending two and one-half miles from both ends of the runways and two miles wide. Once identified, the Air Force was to suggest no residential or similar use be made of the land except for agriculture and light industry. In 1972 the name of the program was changed to Air Installation Compatible Use Zone (AICUZ). The AICUZ program has been undergoing considerable revision since then and is *now* considered *just one* aspect of the broader comprehensive planning processes. "AICUZ is a concept which strives for achievement of compatible land uses around military installations (16:6)." (The reader should note that the Greenbelt and the follow-on AICUZ program, deals with just the land use planning process involving off-base relationships to the flying mission.)

### *Land Use Controls*

Just as the environment and the law was discussed in *previous chapters, here too,* land-use planning must involve some means of control. Vest in his 1973 article, "Protecting Airports and Their Neighbors Through the Environmental Land Use Planning Process," discusses three factors why there is need for airport environs land use controls: legal, practical, and legislative (17).

1. The legal basis is built upon the administrative process of zoning. Zoning takes place when a community designates an area(s) for particular use, usually protecting people from threats to safety, health, and general welfare. *For example, only* the use of zoning prevented construction of slaughter houses in residential

neighborhoods. In the safety-threat arena, government codes prevent and/or limit construction and/or certain land uses because of flooding potential, steep grades, and/or poor soil conditions. Many of us are familiar with the requirements for zoning and lighting related to height obstructions and the control of electronic emissions near airports and air bases. These acts are designed to control and protect low level flight operations. In the health-threat arena, noise is the public issue. Scientific research has been conducted. The limited results to date reveal that both physical and mental hazards are possible depending on the intensity of the noise and the time length the noise was endured. Because the scientific data in this area is limited there is largely a subjective attitude regarding these findings. However, those individuals who have voiced objections do perceive harm. In the public welfare-threat arena the problem is economic in nature. As populations increase near a base or airfield so does the demand for land. Development attracts more growth; and as previously noted, may not be compatible with airport land use planning and environmental programs. The following four quotes typify these influences factors.

> All agencies of the Federal Government shall make available copies of such (environmental impact) statements and the comments and views of the appropriate Federal, State and local agencies, which are authorized to develop and enforce environmental standards . . . to the President, The Council on Environmental Quality and to the public (from National Environmental Policy Act Public Law 91-190, reprinted in 7:3).
>
> All viewpoints—national, state, regional and local—shall, to the extent possible, be fully considered and taken into account in planning Federal or Federally assisted development programs and projects (from Intergovernment Cooperation Act Public Law 90-577, reprinted in 7:3).
>
> Provide state and local governments with information on projected Federal development so as to facilitate coordination with state, area-wide and local plans and programs (from OMB Circular A-95 Implementing Public Law 90-577, reprinted in 7:3).
>
> Development of the plans and facilities shall take into consideration the planning goals of the surrounding community in order that harmonious future relationship may exist between the installation and community. Such planning shall be coordinated with offices of state and local governments, as required by OMB Circualr A-95 (from DOD Construction Criteria Manual Implementing OMB Circular A-95, reprinted in 7:3).

The Air Force continues to pursue its own program which involves both on-base and off-base planning considerations.

There are a number of classic examples where the lack of an overall comprehensive plan and an adequate base and surrounding community land compatability policy has worked against the Air Force's capability to continue performing its mission (1; 13). Urban encroachment to operations must be contended with. Industry and home building is attracted to the airport and air base environs. Some industry or home owners may move elsewhere, others initiate legal or political action. Results thus far to such actions have yielded limited or curtailed air operations. This first economic threat then, is the individual who has to move away, or, because he has been harmed, must pay medical expenses. There is also a second economic loss. It is the multi-million-dollar taxpayer investment if an airport or air base is closed or replaced. In either case the taxpayer ends up "footing the bill" (8;11).

2. The practical basis is built upon the impact to the national defense strategy. When one reviews the projected increases of both commerical and general aviation, it becomes apparent there are very few places where the airways of the United States are not cluttered. This airspace is important to the military training mission.

3. The legislative basis for land use controls is based upon the change in land control from local or home rule to a state and national basis. A national land use policy law to date has not been passed, but there are several bills pending before Congress requesting one (6; 12; 13). There are, however, a number of Legslative or Executive programs that have influenced the Air Force's Oxnard AFB, California and Laredo AFB, Texas resulted in base closure. At Lowry AFB, Colorado, flying operations have been curtailed (16). On the positive side, once local citizens adjacent to Tinker AFB, Oklahoma were informed about the impact a private housing subdivision located directly off the end of the runway could potentially have on the continuance of the base mission, ". . . voted a bond issue to buy properties and relocate 833 houses (11:5)." Not all local community assistance has been directed solely to the flying operation. At Cannon AFB, New Mexico, a citizen's group understanding the importance of providing military families with adequate housing ". . . insured that appropriate adjacent land became available at a reasonable price and actively supported the project from inception to occupancy (11:5)." The comprehensive planning process will also correct those conditions where little or no concern had been previously shown when air operations affect on-base family housing siting or when the housing had been constructed and recreational and/or children play areas were not simultaneously planned for and constructed.

Now that the legal, practical and legislative foundations regarding the control of air base environs have been addressed, the third part of this chapter will cover the Air Force's comprehensive planning process.

## THE COMPREHENSIVE PLANNING PROCESS

By definition, the comprehensive planning process is,

> A process for rational choices between alternative futures assuring orderly physical development with the ultimate objective of promoting and protecting the public health, safety, and welfare, as well as economic and social stability (1; 2).

This process has four distinct phases each essential to the other. Generally the phases are: survey, analysis, plan, and implementation. Before these phases are undertaken however, there is a formulation period where policy must be established. The following seven areas listed in checklist format should be considered when the policy objectives are determined:

1. Health, safety, and welfare

2. Incompatible land uses
3. Noise and accident hazards
4. Land use densities (families/dwellings per acre, etc.)
5. Noise reduction standards
6. Environmental community planning
7. Implementation (both on and off base) (1:3).

Once the policy objectives have been established, the four phases of comprehensive planning can begin.

*Survey Phase*

The purpose of the survey phase is to eveluate existing and proposed land and facility use. The planner must determine both adequacy and suitability for the present and projecting requirements. The following twelve areas listed in checklist format should be reviewed during the survey phase:

1. Land use
2. Noise and accident hazards
3. Social needs and wants of the people
4. Quality of living standards/conditions
5. Community services
6. Utilities
7. Facility conditions
8. Economic and fiscal structure
9. Physical and ecological characteristics of environment
10. Transportation/circulation systems and characteristics
11. Community governmental structure
12. Legal aspects of state and local areas (1; 3)

In all cases this inventoried data should be quantified so that important factors can be emphasized and related to known features of the project under consideration. It is important the planner recognize that not all the information he gathers in this survey phase may be initially used. However, his inventory of the existing situation should still be thorough enough to provide a foundation for developing alternatives should the original objective become infeasible. In researching the aspects of the survey phase, in the private sector, Rubenstein follows a similar step-by-step procedure and has categorized these items into natural factors, cultural factors and aesthetic factors (10:10).

*Analysis Phase*

The purpose of this phase is to determine what are the knowns and unknowns and arrive at the impact they have on the specific objective at hand. Again, the checklist format aids in identifying the various steps of this phase.

1. Net change between existing situation and future needs.
   a. Impact on operations
   b. Impact on community services
   c. Impact on land uses
   d. Impact on environment
2. Land use determinants
3. Land use relationships
4. Current litigations
5. Facility condition codes and category codes (these are specific Air Force Civil Engineering identification numbers used for real property management and facilities project programming requirements)
6. Intergovernmental relations (Housing and Urban Development, HUD, Health, Education and Welfare, HEW, and Federal Housing Administration, FHA) (1; 3)

The analysis phase ends when the planner perceives he has adequate information to develop the plan. In this case, he must convince himself he knows what the requirements are, so that he can continue with the next step of the process; e.g., that of documenting "his road map" to achieve the desired objective (1).

*Plan Phase*

The purpose of this phase is to relate the functional arrangements in terms of various individual plans. Similar items are grouped and incorporated into the respective functional plans (13). Linkages play a very important role in this phase. Rubenstein points out that linkages or ties can involve ". . . movement of people, goods, communication, or amenities (10:26)." It is these linkage relationships with project site, on-base and adjacent off-base properties, and those of the total "base-city" complex that will influence how well the Air Force makes use of its land use. The following fifteen plans are used to delineate the various functional/linkage relationships.

1. Land Compatibility Plan
2. Recreation and Open Space Plan
3. Transportation Plan
4. Air Installation Compatibility Plan (AICUZ)
5. Community Center Plan
6. Facility Improvements Plan
7. Facility Maintenance Plan
8. Space Requirements Plan
9. Housing Improvements and Construction Plan
10. Natural Resources Plan
    a. Fish and wildlife
    b. Environmental Quality
    c. Ecological Systems and Locations
11. Encroachment Plan
12. Land Management Plan
13. Landscape Plan
14. Airfield and Airspace Plan
15. Management Strategy Plan (1; 3).

The melding of these fifteen documents completes the plan (documentation) phase in narrative and/or graphical form. The planner has now documented "his road map" and can now move to the implementation phase.

*Implementation Phase*

The purpose of this phase is to execute the desired objective and perform an ongoing update program through base and major command reviews. One of the key requirements of this phase is the coordination with local and state governments. By performing these communication exchanges the Air Force will insure there is continuous awareness with the public, which will contribute positively to the base's development and continuance of its mission (8; 11; 13). The checklist format of the implementation phase follows:

1. Phased objectives
2. Funding avenues through Major Commands and Headquarters USAF
   a. Disposal
   b. Non-appropriated funds
   c. Army-Air Force Exchange Services
   d. Commissary surcharge
   e. Housing
   f. Military Construction Program

g. Operations and Maintenance
h. Land acquisition
i. Jointly with city, county, state, federal
3. Community Regulatory Process
a. Office of Management and Budget Circular A-95
b. Planning commissions
c. Zoning boards
d. City or intergovernment councils (3)

The implementation phase of the planning process is primarily concerned with the approval of the comprehensive plan and is not contingent on physical construction because the plan is continually reviewed at both base and major command level. The implementation phase includes the preparation of project planning/programming documents or similar documents, accounting for construction, disposal, conversion and/or modernization as needed (13:12; 7). The reader can see that creating and maintaining the Comprehensive Plan is a very complex process. The next part of this chapter looks at only the high points of those elements that make up the Comprehensive Plan.

## THE ELEMENTS OF THE COMPREHENSIVE PLAN

The writer has elected to include only the major elements of the Comprehensive Plan because of the specific importance the plan plays in the overall decision making process of the Air Force in dealing with the environment, base mission changes, and community socio-economic impacts. The Installations' Comprehensive Plan is presently planned to be composed of nine parts. Air Force Civil Engineering has designated these parts as "Tabs." Each tab contains specific information related to the "base-city" complex in narrative and/or graphical format. Even though the Base Civil Engineering organization is the focal point for the preparation of this plan, participation from all base level activities is necessary (i.e., legal, safety, information, operations, aircraft maintenance, logistics, comptroller, medical services, weather, services and consolidated base personnel) (14:2).

The major elements are as follows:

*A. Tab A - Narrative*

1. A-1: *Environmental Narrative*

a. Summary—identification of major problems and environmental constraints of the base and local community. (facilities/housing, capital investment, availability and limitations of utilities and energy sources, geographic location, size of airspace availability, pollution abatement, encroachment, communicative and transportation, reserve component support, civilian work force, community, history of the base in the past and today)

b. Existing Mission Description—flying and non-flying units

c. Air Operation Characteristics—air space concept, requirements, arrivals/departures, accident record/flight hazards, regional air traffic, air space evaluation, maintenance/aircraft ground operations

d. On-Base Characteristics—summary of mission, personnel, support facilities, services (health, education and welfare), utilities, demographics, land use, transportation.

e. Natural Resources—land, air, water, ecological (vegetation, forestry, fish and wild life, outdoor recreation, range management, crop lands

f. Civilian Community Characteristics—public facilities, services, utilities, demographics, land use, transportation, political/legal jurisdictions and ordinances

g. Economic Characteristics—base and community payrolls, employment, budgets, economic impact to taxes and retail/wholesale sales

h. AICUZ—(This would be the base's phase IV report). (1) A strategy used to cooperate, inform, and assist off-base planning officials on compatible land use guidelines; (2) A documented concept that has been used to determine land uses that are compatible with aircraft operations. The planning factors include runway alignments, noise, flight patterns, aircraft, and potential accident regions.

2. Tab A-2 To be announced in near future.

*B. Tab B - Area Maps*—regional and vicinity

*C. Tab C - Basic Plans and Data*—(Existing) Base Plan, road map, real estate map, airfield pavement plan, soil boring plan, aerial photos, landscape plan

*D. Tab D - Meterological Date*—temperature, humidity, precipitation, wind, etc.

*E. Tab E - Airspace Obstructions*—Approach/departure paths with obstructions

*F. Tab F - Development Plans*—(Proposed) development plan, vicinity noise map, base noise contour map, landscape plan

*G. Tab G - Utility Plans*—water, sanitary sewage, storm drainage, electrical distribution, central heating, natural gas distribution, airfield lighting, communications, navigational aids, liquid fuel systems (4:14).

## CONCLUSION

The Air Force land use planning program has begun to derive benefits that have been in the mutual interest of many installations and the local and regional communities within their environs. The AICUZ portion of the land use program thus far has been the predominate program, but once the AICUZ strategy has been agreed to by both Base and its adjacent communities, the on-base land use planning program can be expected to assume its place in the "ecosystem" (16). As McHarg points out, ". . . we seek not to optimize for single, but for multiple compatible land uses (9:144)." By determining the degree of compatibility ". . . the nature of the place may be learned. . . . The place must be understood to be used and managed well. This is the ecological planning method (9:144)."

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# CHAPTER VII — OCCUPATIONAL SAFETY & HEALTH ACT (OSHA)

## OSHA APPLICATION IN PRIVATE INDUSTRY

By Theodore L. Brown, Maj. USAF

*Introduction and Need for the Occupational Safety and Health Act*

The United States Federal Government has become more and more involved in regulating private industry throughout the nation. There have been many laws and executive actions which have impacted on business operations through either increased regulation or costs. Businessmen have been confronted with wage and price controls and legislation such as the Equal Employment Opportunity Act, Environmental Protection Agency legislation, and in 1970, the Occupational Safety and Health Act(OSHA). The Occupational Safety and Health Act appears to be one of the most complex and comprehensive efforts of the government to perform its regulatory duties. Within the scope of this law is virtually every employer and employee in the United States (5:57). The stated purpose of the law is all encompassing "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources (6:1101).

Prior to the law's enactment, Bureau of Labor statistics indicated that from 1961 to 1970, disabling injuries increased 29 percent—from 11.8 to 15.2 per million manhours worked. Additionally, it was estimated by the United States Public Health Service in 1970 that 390,000 persons contract occupational diseases each year. It was statistics such as these which prompted congress to explore avenues of corrective action which would reduce personal injuries and illnesses arising out of work situations. These personal injuries and illnesses were imposing a serious detrimental impact on the nation in the form of lost production, wage loss, medical expenses and disability compensation (6:1101).

As congress investigated to determine what corrective action would be necessary, it was self-evident that something was needed with sufficient national impact to put environmental occupational protection in proper perspective. Congress found that some states had no safety and health laws of any description, and other states had fair laws; however, they either lacked ordinances to enforce them or ordinances in existence were not enforced (9:107). With the Occupational Safety and Health Act of 1970, sponsored by Williams and Stieger, congress attempted to assure safe and healthful working conditions for all working men and women. This was to be accomplished by authorizing enforcement of the standards developed under the Act in assisting and encouraging the states to assure safe and healthful working conditions. In addition, the Federal Government would provide for research, information, education, and training in the field of occupational safety and health (6:1101).

*Who is Affected by the Act*

The Occupational Safety and Health Act was enacted in 1970, but did not go into effect until April 28, 1971. Its purpose, as was previously stated, is to preserve our human resources by assuring that working conditions are safe and healthful. The law applies to every employer in the 50 states, District of Columbia, Puerto Rico, Virgin Islands, Wake Island, America Samoa, Guam, Trust Territory of the Pacific Islands, Outer Continental Shelf Lands, Johnston Island, and the Canal Zone when the employer has employees and is engaged in commerce. This law specifically excludes federal, state, and local government employees; however, it does provide for equally effective coverage of these employees under other programs and laws as may be necessary. It places on the employer the responsibility of providing a work place free of hazards which could cause serious injury or death. The employer must comply with the safety and health standards which are published as a result of the law. The employer has a responsibility also. He or she must comply with all safety and health standards, rules, regulations, and orders pertaining to their conduct under the law (1:1201).

*Responsibility for Administering the Act*

The Secretary of Labor has been assigned the overall responsibility for publishing and enforcing job safety and health standards. Enforcement will be accomplished by inspection of work environments. Occupational safety and health inspectors located throughout the nation and its territories will visit work sites and document violations of the law. The inspector must issue a citation for violations which can result in the employer being fined for noncompliance. The Secretary of Labor is assisted in the administration of the Occupational Safety and Health Act by a three-member board, appointed by the President of the United States and titled the Occupational Safety and Health Review Commission. He is also assisted by the Secretary of Health, Education and Welfare (HEW) (1:1201). The Occupational Safety and Health Review Commission is a quasi-judicial board which reviews cases of alleged violations brought before it by the Secretary of Labor, and if warranted, it issues corrective orders and assesses civil penalties (1:1205). The Secretary of Health, Education, and Welfare will provide for research and related functions pertaining to occupational safety and health standards. The newly created National Institute for Occupational Safety and Health within HEW will be the responsible agency for these functions (1:1201).

*What OSHA Actually Does and How it Applies to Industry*

The occupational safety and health standards under the Act are really nothing more than rules for avoidance of hazards. These rules can be compiled by research or experience. The standards may be common to all employees or only to those workers engaged in specific types of work. An example of a standard which would apply to all employees is fire protection. An example of a more specific standard would be one for handling compressed gasses. Because of the enormous task of compiling a volume of standards which would apply to all employers and all employees of the nation, the Secretary of Labor was given two years after the date of the law's enactment to compile the standards without complying with the rule-making requirements of

the Administrative Procedure Act. This allowed the Secretary of Labor to immediately implement existing federal standards and national concensus standards. Such standards as those applying to federal contractors under the Welsh-Healey Act and standards of the National Fire Protection Association were immediately published as occupational safety and health standards under the law. During this two-year period, new standards developed by research accomplished by the Secretary of Health, Education, and Welfare, advisory committees and others could be published as a standard under the law. In addition, revisions to existing standards could be made without complying with the Administrative Procedure Act. In cases where extreme danger is involved, the Act provides for establishment of emergency standards effective upon publication in the Federal Register. Should any of the standards which are issued adversely affect any person, that person can challenge its validity by petitioning the United States Court of Appeals within 60 days after it is published. The standard will remain in effect unless ordered otherwise by the court. Submission of the petition doesn't stay the standard. An employer can apply to the Secretary of Labor for a variance on a standard, and if adequately justified, the Secretary of Labor may grant a time extension of compliance. Additionally, the Secretary of Labor can grant a variance if the employer used equal or higher standards than those published under the Act (1:1201-1202).

Violations of occupational safety and health standards can come to the attention of the Secretary of Labor in one of two methods. Any employee or employee representative who believes that a safety or health standard violation exists may request an inspection of the work site by sending a signed written notice to the Department of Labor. If the violation is such that there is imminent danger in injury to an employee, the employee may go directly to the United States District Court to secure a restraining order should the Secretary of Labor arbitrarily or capriciously fail to seek action to abate such danger. Employees who must take such action as reporting suspected violations are protected from harrassment under the Occupational Safety and Health Act. If an employer discharges or in any manner discriminates against any such employee, the employee can take action through the Secretary of Labor and the United States District Court for appropriate relief. This complaint must be filed with the Secretary of Labor within 30 days of the illegal action (1:1020-1203).

The second method that the Secretary of Labor learns of violations is from occupational safety and health inspectors who conduct inspections of employers' work facilities. These Department of Labor safety inspectors may enter any establishment covered by the Act for the purpose of inspecting the premises and all working conditions to insure compliance with occupational safety and health standards. When violations are found, citations are issued in writing describing the specific nature of the violation and fixing a reasonable time for abatement of the violation. The employer is notified by certified mail of the penalty if any is assessed. This is usually accomplished within a reasonable time after issuance of the citation. If the employer wishes to contest either the citation or proposed assessment of penalty, the department of Labor must be notified within 15 working days after the employer receives notification. If the employer fails to act within the 15-day time limit, the citation or assessment of penalty is final. If the employer does contest a citation or assessment within the time limit, the Occupational Safety and Health Review Commission will conduct a hearing and as a result will issue orders affirming, modifying, or vacating the citiation or penalty. Should the employer wish to contest any order of the commission, a review may be requested in the United States Court of Appeals. The request must be accomplished prior to 30 days after issuance of the commission order or the order is final (1:1202).

As with citations and assessment of penalties, the abatement period may be contested. The employer or an employee may within 15 days after notice contest the abatement time by notification filed with the Department of Labor. The employer may file because the abatement time is considered to be too short while the exployee may file because the abatement time is considered to be too long. The Occupational Safety and Health Review Commission will hear the complaint and issue an order. The abatement period in contested cases will not begin until the Commission issues the order (1:1203).

Should an employer not correct a violation within the authorized abatement time, a penalty may be assessed. The employer may contest the penalty within 15 days by filing notice with the Department of Labor. If an employer exceeded the abatement time due to circumstances beyond his control, the Occupational Safety and Health Review Commission will conduct a hearing and issue an order either affirming or modifying the abatement order (1:1203).

The maximum penalty which may be assessed for each violation is $10,000. A serious violation is one where there is a substantial probability that death or serious physical harm could result. Violations of this nature carry a mandatory penalty of up to $1,000 each. If a death should occur as a result of a violation and the employer is proven a willful violator, the penalty may be increased up to $10,000 and six months imprisonment. A second conviction under these circumstances doubles these penalties. Criminal penalties may be assessed for making false official statements or giving advance notice of inspections conducted under the Occupational Safety and Health Act (1:1203).

Employers must maintain records of work related deaths, injuries, and illnesses. This includes medical treatment, loss of consciousness, restriction of work or motion, or transfers to another job. It also includes employee exposure to potentially toxic materials or harmful physical agents which require monitoring and measurement under the act. The employer is required to make his records available to the Secretary of Labor or the Secretary of Health, Education, and Welfare upon request. The secretaries may require the employer to conduct and record self-inspections and employers must keep employees informed of their protections and obligations (1:1203).

Employers may be required to submit reports of work injuries and illnesses to the Department of Labor. These reports will become part of a program conducted by the Secretary of Labor in which collection, compilation, and analysis of statistics on work injuries and illnesses are done on a national level (1:1203).

The Federal Register is used as the vehicle to keep employers and employees familiar with action taken under the Occupational Safety and Health Act. The

Secretary of Labor must publish therein a statement of his reasons for any action he takes with respect to the publication of any standard, the granting of any exemption or time extension, or the issuance of rules, orders, or decisions pertaining to the standards. This includes any compromise, mitigation, or settlement of any penalty assessed as a result of the Act (1:1203-1204).

Although the Act was necessitated by the lack of state programs, it encourages the states to develop their own programs and assume the fullest responsibility for the administration and enforcement of occupational safety and health laws and regulations. In promoting state participation, the Federal Government will provide grants and will allow the states to assume full responsibility upon approval of the state plan by the Secretary of Labor. In order to have the plan approved, the state must designate a responsible agency or agencies to carry it out. Standards must be at least as effective as federal standards, inspections of work places must be made without notice, and adequate funding must be available for administration and enforcement. There must be a job safety and health program in effect for public employees within the state as permitted by law, and the state must report to the Federal Government as required. After the state plan has been approved, federal authorities may continue to exercise federal authority until there is satisfaction that the state program is adequate. There will be continuing evaluations of the state plan by the federal authorities, and if necessary, withdrawal of approval can occur whenever there is failure to comply with federal criteria (1:1204).

The Secretary of Labor in association with the Department of Health, Education, and Welfare must develop and provide education and training programs for employers and employees. Under the act, employers and employees must be taught recognition, avoidance, and prevention of unsafe and unhealthful working conditions. Additionally, these departments must provide education and training for occupational safety and health inspectors to insure proper enforcement of the Act (1:1205).

The National Institute for Occupational Safety and Health (established within HEW) performs research and educational functions. It develops and recommends occupational safety and health standards. Additionally, the Institute may develop regulations requiring employees to monitor employee exposure to toxic agents and to have employees get medical examinations in conjunction with a federal study. The employer can get financial assistance in connection with such studies under provisions of the Act (1:1205).

The Occupational Safety and Health Act does not affect workman's compensation laws as such; however, there is a provision for a 15-man national commission on State Workman's Compensation Laws to determine if laws provide adequate, prompt, and equitable compensation in the event of an injury or death in the work place. The Act also includes amendments to the Small Business Act whereby small businesses can get financial assistance to insure compliance with the standards. Loans can be secured to change equipment, facilities, and methods of operation (1:1205).

Other provisions of the Act provide for advisory committees to assist the Secretary of Labor, guidance on information collection to place a minimum burden on the employer and avoid duplication, legal representation for the Department of Labor, protection of trade secrets, avoidance of serious impairment of national defense, protection of Department of Labor inspectors, annual reports, a new Assistant Secretary of Labor, and appropriations authority (1:1205-1206).

*Private Industry's Grievances About OSHA*

It is not unexpected that a law as comprehensive as the Occupational Safety and Health Act would create unrest among the nation's businessmen. On May 29, 1971, one month after the law became effective, 248 large pages of print in the Federal Register were required to publish the standards which had been made mandatory at that time. Additionally, there were other documents such as rules and regulations that when put in a single stack were over 17 feet high. It was extremely difficult for the employer to research these documents and pinpoint those portions which applied to his situation because the Department of Labor had no index available (10:2-4).

The authority to conduct unannounced inspections of the employer's facilities adds to the apprehensiveness of the employer. To the employer, the intent of the Act does not appear to be the correction of violations so much as to catch the employer committing them. It is of concern to employers that these unannounced inspections can be initiated by an "anonymous informant" who may be a current employee or he may be a sorehead who has been fired or quit his job and wants some sort of revenge. The employer is concerned that during an inspection if a "serious" violation is detected, there must be a fine. This allows no discrimination between the unwillful and willful violator except by the amount of the fine. Should the employer wish to contest a citation or penalty, he must request a hearing before the Occupational Safety and Health Review Commission. Since the commission is a part of the Department of Labor and the hearing examiners act as "judges," the exployers contend that this is a violation of the principle of separation of powers which is paramount to our tripartite system of government. Another ramification of the Act which concerns employers is that when a violation is detected, an abatement period is arbitrarily set and if the employer should not correct the violation within the prescribed time, he can be fined up to $1,000 per day until he does so (10:4-6).

Employers regard the Act as one-sided against the employer. The reason for this is that nowhere in the Act is there any mention of penalties for employees should they not comply. Corrective action to be applied to a noncomplying employee is the full responsibility of the employer. The employer must then run the risk of the offended employee anonymously notifying the inspectors of possible violations and causing the employer to be inspected. It is not that the employer is violating the standards willfully that causes concern over inspections—its the fact that any inspection can uncover violations which can cost the employer time and money (10:5).

When the employer reaches the 248 odd pages of standards in the Federal Register to determine what is required, he many times finds the standards so unclear that he is genuinely confused. Sometimes if the standard is clear, he is still confused as to what he is required to do as an employer to comply with the standard. There are also industries which are considered high risk or

target industries. These are roofing and sheet metal, meat and meat products, lumber and wood products, manufacturers of mobile homes, campers, snowmobiles, and stevedoring. These industries can figure that the probability of inspection is high while other industries can figure on a much lower probability (2:63).

Although the employer has the right to contest a citation or penalty, its desire to do so has been dampened by the feeling that the Review Commission could take a position of increasing penalties of those who do file contests (7:1). It also has been suspected that those employers who propose amendments to the Act can expect a visit from Occupational Safety and Health inspectors (7:2-8). One of the main problems is that the employer feels he cannot deal directly with the Occupational Safety and Health Administration to find a solution to his problem or get a clarification of a standard. Unless the employer communicates as an anonymous informant, it is felt that he could be fined for a violation he exposes, or it could trigger an inspection of his facility (10:5).

Another employer complaint is that the Occupational Safety and Health Act is adding tremendously to the employers' cost of doing business. This is brought about in two ways—(1) it costs to change facilities and procedures to meet the standards and (2) when inspected, if violations are found, the employer must pay fines. It is felt that these costs will drive the small employer out of business (10:12-13).

There have been problems which can be attributed to the "start-up" process of enforcement of the Act. Some of these have been trivial, irritating, and costly to employers. An example of one such problem is that the Act requires separate restrooms for male and female employees, regardless of the size of the business. Another requirement is that toilet seats must be split and that a hook must be in the restrooms for coats. Employers felt that these types of requirements were a result of the haphazard and rapid collection and publication of standards (2:59-60).

Employers recognize that the Occupational Safety and Health Act will have a significant impact on labor relations. As employees become more familiar with their rights under the Act, it will be more difficult to negotiate and administer contracts. Employers feel that the Act gives more power to the union by using the Act as a lever in negotiations (2:61).

Employers have not been happy with the Occupational Safety and Health Act. They describe the purpose of the Act to be to strangle businessmen with regulations. Employers consider the Act to be confusing, harassing, and bankrupting. There have been no fewer than 100 bills introduced in congress designed to amend the law. Employers would like to see its impact softened through reduction of its coverage (11:60-61).

### *OSHA and Small Business*

The employer who employs fewer than 15 to 25 employees feels that he should be exempt from the law's coverage because of the added expense of compliance and the record keeping involved. There are several reasons why this will not come about—(1) statistics indicate that 30 percent of the nation's workforce would be exempted from protection afforded by the Act, (2) statistics indicate that small businesses have the highest injury rate, (3) if a small subcontractor was exempt on a large project, it would cause undue risk for all workers, and (4) it would put large employers at a disadvantage competitively because safety and health standards compliance is costly. Although exemption appears to be out of the question, other aid is being given. One type of assistance is that Small Business Administration Loans are available to help with the costs of compliance. Additionally, occupational safety and health administration safety and health courses could be developed specifically for small companies in certain industries (2:62-63, 67).

### *What the Occupational Safety and Health Administration is Doing to Relieve Industry Grievances*

The Occupational Safety and Health Administration is trying to relieve some of the antagonism that exists in industry toward the Occupational Safety and Health Act. One of the largest single factors which promotes this antagonism is that employers do not understand this comprehensive and complex program and its legislation. One of the methods that officials of the Occupational Safety and Health Administration have used to increase understanding of the organization and its activities is through question and answer sessions with the press. A panel of 10 officials from the administration and 60 members of the press met in May of 1973 in an effort to broaden the understanding of what the Occupational Safety and Health Administration is trying to accomplish. This indicates that the administration is sensitive to the criticism that it faces, both from the public and congress (3:6).

The Occupational Safety and Health Administration recognizes that compliance officers or inspectors are human and are subject to all the human failings. Their backgrounds are diverse and their educations vary from the self-taught with no college to the graduate safety engineer. In an effort to prepare the compliance officers for their assigned duties, the Occupational Safety and Health Administration Training Institute was established at Rosemont, Illinois. The school has a curriculum of 17 different courses, a full-time staff of 13 safety and health professionals, and 100 to 125 people outside the service who can be consulted for expert help. The basic training course is roughly divided as follows: 25% for compliance procedures, 50% for study of standards, and 25% for application of standards and procedures. This includes case studies and workshops. After a compliance officer has been trained, he must then make his first inspection with an experienced inspector. The compliance officers are not primarily interested in penalizing employers, but they are interested in providing safety and health for the American worker at his work place. They are being trained to detect violations of safety and health standards and these violations can result in penalties. Some of the violations that the inspector cites will be considered nit-picking and some violations will be missed. These problems cannot be completely eliminated by training; however, the inspector's performance can be greatly improved. It is anticipated that the image of the compliance officer which will emerge is that he is human and a servant of the people (4:33-36).

The Occupational Safety and Health Administration is reorganizing. It is sharing more of its compliance burden with the states, placing more emphasis on standard setting and decentralizing its training function. It is also trying to better inform people of their rights and responsibilities under the law. In answering the two main complaints of employers—"on-the-spot-citations"

and "instant penalties," the Assistant Secretary of Labor has emphasized that these allegations are not true. The inspector cannot issue citations or penalties on-the-spot. To correct misunderstandings of this nature, more emphasis is being placed on the final phase of the inspection which is in the nature of a closing conference. Inspectors are being told to stay in the closing conference until the employer understands what has been found during the walk around. It's during this conference that the employer should get a better understanding of what the administration is trying to accomplish and how the citation and penalty process work (12:30-40).

Employers have voiced opinions that the Occupational Safety and Health Administration and the Occupational Safety and Health Review Commission are one and the same. This could come about by the use of the acronym OSHA indiscriminately to signify the law itself, the administration agency implementing the law, and the Occupational Safety and Health Review Commission. The Chairman of the commission and his fellow commissioners have tried to correct this misunderstanding by emphasizing that the employer can get a fair hearing and that the burden of proof is on the Secretary of Labor and not on the employer. It has been pointed out previously that if an employer wishes to appeal a ruling of a judge, he can file for a hearing before the three Commissioners of the Occupational Safety and Health Review Commission. If he is still unsatisfied, he may file an appeal with the federal court. These are some issues which will not be settled until there have been landmark cases in the courts (8:41-43).

*Conclusion*

The largest problem in attaining the goal of the Occupational Safety and Health Act is education—not political as one might think. This new responsibility which has been thrust on the employer requires training personnel in large numbers. The educational system of the country has not had occupational safety and health curriculums geared to supplying the employer with the highly knowledgeable training person that is needed today. It has been emphasized that the act itself will not cure the occupational safety and health problem with which our country is faced. The answer is in the responsible leadership in each work place. This leadership can only come about if there is a highly professional occupational safety and health expert available to tell management what is required, sells them on the need for it, and sees that it gets done. The Secretary of Health, Education, and Welfare is funding college and university curriculums to help meet the need; however, it will be some time before the results can be measured (9:108-110).

Environment occupational safety and health regulation in the work situation is here to stay. The human resources of our nation must be protected. The National Safety Council estimates that yearly injuries disable 2.2 million employees and cause the death of 14,000 more. The Occupational Safety and Health Administration estimates that diseases disable 390,000 employees and cause 100,000 employee deaths in a year. All of these injuries and diseases occur because of unsatisfactory work environments—this certainly justifies the attention of the United States Government (2:58). The Occupational Safety and Health Act and private industry can be compatible—together they should reduce the frightening figures which have been cited. "The Act, essential as it is, is only a mechanism. Environmental occupational protection is a people problem, is people oriented and people produced and solved (9:110)."

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# CHAPTER VII — OCCUPATIONAL SAFETY & HEALTH ACT (OSHA)

## OSHA APPLICATION IN GOVERNMENT AGENCIES

By John C. Nicholson, Capt, USAF

*Introduction*

> There has been much discussion in recent months about the quality of the environment in which Americans live. It is important to note in this regard that during their working years, most American workers spend nearly a quarter of their time at their jobs. For them, the quality of the workplace is one of the most important of environmental questions. The protection of that quality is a critical matter for government attention (4:21:0141).

With these opening remarks, President Nixon revealed his intent to submit to the Congress a bill which was subsequently passed entitled the Occupational Safety and Health Act of 1970. The purpose of the Occupational Safety and Health Act (OSHA) is "to assure so far as possible, every working man and woman in the nation safe and healthful working conditions (5:71:1101)." To achieve this goal, each employer must furnish "each of his employees employment and places of employment free from recognized hazards, causing, or likely to cause death or serious physical harm (5:71:1102)." The responsibility of each employee is to "comply with these safety and health standards, and all rules, regulations, and orders issued pursuant to the Act which are applicable to his own actions and conduct (5:71:1102)." OSHA became effective on 28 April 1971.

The OSHA legislation authorizes the Secretary of Labor to set and enforce mandatory occupational, safety, and health standards applicable to businesses affecting interstate commerce. To enable him to fulfill his duties, the Secretary established the Occupational Safety and Health Administration (OSHA) headed by the Assistant Secretary of Labor for Occupational Safety and Health. This agency consists of 10 regional offices, 49 area offices, and 2 maritime district offices in major cities across the nation (2:13). The Act also established the Occupational Safety and Health Review Commission to resolve objections presented by employers to citations, or proposed penalties resulting from enforcement proceedings of the Department of Labor. In addition, the Act created the National Institute for Occupational Safety and Health (NIOSH) within the Department of Health, Education, and Welfare (HEW). This office was established to carry out the responsibilities of the Secretary of Health, Education, and Welfare which are to develop and carry out "a broad program of study, experiement, demonstration, education, information, and technical assistance as further means of promoting better safety and health practices in the work place (4:21:0142)."

*Standards*

To provide the necessary impetus to "get the show on the road," the Secretary of Labor was permitted until 28 April 1973 to issue any existing Federal or National consensus standard as an OSHA standard without regard to the administrative rule-making procedures incorporated in the Act. On 29 May 1971, OSHA issued its initial standards which included:

1. Standards promulgated under the Construction Safety Act of 24 April 1971.
2. Maritime standards from the Longshoremen's and Harbor Workers' Compensations Act.
3. Established Federal standards from the Walsh-Healy Act.
4. National consensus standards developed by the American National Standards Institute and the National Fire Protection Association (2:7).

These initial standards constitute a foundation or starting point. Subsequent standards may originate from sources within the outside of the Department of Labor; however, proposed new standards are at the discretion of the Secretary, subject to the review of an advisory committee appointed by him to assist in standard-setting functions. Such a committee must include one or more members of HEW, representatives of the employers and employees involved, representatives of state, health and safety agencies and may include recognized authorities in occupational safety or health, and representatives of standards-setting organizations. Regardless of its source, once the proposed standard has been reviewed by an advisory committee and tentatively approved by the Secretary, it is published in the Federal Register. Any interested party is allowed thirty days after publication to submit written data or comments. If objections are filed, the Secretary conducts hearings to determine the adequacy of the proposed standard. Sixty days after the hearing, or if no objections are received ninety days after initial publication in the Register, the new standard may be issued.

*National Institute for Occupational Safety and Health*

The National Institute for Occupational Safety and Health was established by the Act to conduct research and experimental programs to develop criteria for new and improved occupational safety and health standards, and to recommend to the Secretaries of Labor and HEW the adoption of these standards. In fulfilling its duties and responsibilities, the Institute is charged with "prescribing regulations requiring employers to measure, record, and make reports on the exposure of employees to potentially toxic substances or harmful agents which might endanger their safety and health (1:71:1205; 5:71:1112)." It must also annually publish a list of all known toxic substances and the concentrations at which toxicity is known to occur. A final major duty is, upon written request of any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects. Its determinations, in this regard, are provided to the employer and the affected employees.

*Application of OSHA in the Federal Sector*

The original Act specifically excluded Federal, State, and Local Government employees from coverage (1:71:1201). The Public Law did, however, direct the head of each Federal agency to establish and maintain an effective and comprehensive occupational safety and health program consistent with standards issued under the Act (5:71:1111). President Nixon, in Executive Order

11612, 26 July 1971, expressed his desire that the Federal Government "set an example for safe and healthful employment (3:71:9501)." The executive order dictated that each agency head would designate a qualified responsible person to manage each agency's safety program. It also delineated responsibilities for establishing safety policy and an organization with procedures to implement and evaluate the effectiveness of the program, including a management information system and periodic inspections of work places.

The Secretary of Labor was directed to provide guidance to the Federal agencies by publishing regulations designed to assist them in fulfilling their responsibilities. He was also tasked to annually evaluate the programs of each agency, and, with the consent of the agency head, conduct investigations to determine program effectiveness. To assist him, the Secretary established the Federal Safety Advisory Council composed of representatives of Federal agencies and representatives of labor organizations representing employees. The purpose of the council was to recommend to the Secretary procedures for implementing OSHA in all Federal agencies.

In response to Executive Order (EO) 11612, some Federal agencies belatedly attempted to execute their responsibilities. For example, the Department of Defense issued DOD Instruction 5030.52, 28 April 1972, stating its policy "to use and develop as necessary, safety and health standards equal to or better than those promulgated for the private sector (8:2)." It also levied upon the Director of Safety Policy, Office of the Assistant Secretary of Defense (Manpower and Reserve Affairs) the overall responsibility for monitoring and evaluating DOD compliance with OSHA and EO 11612. The instruction further stipulated that DOD components would, as a matter of normal operations, conduct a technical review of all OSHA standards and identify inconsistencies between OSHA standards and those contained in existing manuals, instructions, orders, and regulations. As a general rule, DOD components would amend existing guidance as necessary to insure consistency with OSHA standards. Where deviations were considered necessary, the DOD component was required to justify and document the existing condition or practice as being at least as safe as conditions prevailing under the OSHA standard. Implementing instructions of each DOD component were required to be submitted to OSD within sixty days.

Other Federal agencies made varying attempts to implement EO 11612; however, at the request of the Chairman of the Committee on Labor and Public Welfare, the General Accounting Office (GAO) conducted a review of OSHA's effectiveness in implementing the Act in Federal agencies. The findings of the GAO were startling. Some of the major recommendations contained in the report were that:

1. OSHA issue the regulations required by EO 11612 providing guidance to Federal agencies in developing and implementing effective occupational safety and health programs.

2. Each Federal agency should conduct a comprehensive work place survey to ascertain deficiencies and the costs associated with correcting them.

3. Despite OSHA's belief that "primary responsibility for a safety and health program rests with the Federal agencies, and that they, not OSHA, should insure its implementation," independent inspection of work places to ensure compliance should be conducted by OSHA (2:58-59).

Prompted by the findings of the GAO report, the Department of Labor published in the Federal Register on 28 September 1973, proposed rules for the safety and health of Federal employees for public comment. The response was so overwhelming and varied that the rules were subjected to review and revision by the Department of Labor and the Federal Safety Advisory Council. It was approximately one year later that final rules were approved and published.

During October 1974, simultaneous publication of EO 11807 and Safety and Health Provisions for Federal Employees occurred. President Ford reiterated the Federal government's "obligation to set an example for all employers by providing a safe and healthful working environment for its employees (6:35559)." The EO contained specific guidance for evaluation of each Federal agency's occupational safety and health program by the Secretary of Labor and provision of these evaluations to the President. He charged the Secretary of Labor to provide detailed guidance to all agencies in establishment and implementation of their programs. The President amplified the specific duties and responsibilities of the head of each agency and those of the Secretary of Labor. For example, the Secretary of Labor upon request of an agency will:

1. Evaluate agency working conditions recommending appropriate standards to be adopted.

2. Inspect workplaces to identify unsafe or unhealthful working conditions and assist in correcting such conditions.

3. Train appropriate agency safety and health personnel.

4. Annually evaluate the safety program of each agency employing more than 1000 persons through such headquarters or field reviews the Secretary deems necessary (6:35561).

*OSHA Provisions for Federal Employees*

At the same time that EO 11807 was issued, the Department of Labor published Safety and Health Provisions for Federal Employees. These provisions were designed to implement Section 19 of the Occupational Safety and Health Act of 1970 and the Instructions of Executive Orders 11612 and 11807. The rules contain the guidance previously lacking and includes some detailed instructions not previously noted. For example, the Department of Labor will prepare and distribute handbooks to assist agencies in observing the guidelines of the Secretary in accordance with agency missions, sizes and organizations (9:36455).

The guidelines are subdivided into six major sections dealing with the following:

1. General
2. Record keeping and reporting occupational injuries, illnesses, and accidents
3. Agency organization
4. Procedures for inspections and abatement
5. Agency occupational safety and health standards
6. Field Federal safety and health councils.

The general section encompasses the purpose of the provisions, applicability of the guidelines, and definition of terms. The key points to this section are that the

guidelines do not apply to employees of private contractors performing work under government contracts, even though such contractors may be using government owned or leased facilities and equipment. It also defines such nebulous terms and phrases as "consultation with representatives of the employees thereof" and "reportable occupational injuries or illnesses." Complete understanding of these and other terms is crucial to establishment of the required safety management information system.

The second section dealing with record keeping and reporting dictates that separate logs of all recordable occupational injuries and illnesses be maintained for civilian and noncivilian (presumable military) employees where both are employed at a single establishment. It also requires that a detailed supplementary record be maintained for each occupational injury or illness. Moreover, this section prescribes quarterly and annual summaries of injuries, illnesses and accidents to be forwarded to the Department of Labor. These summaries must be posted or otherwise disseminated in written form to all employees. An employment accident resulting in the death of one or more employees, the hospitalization of five or more employees, or resulting in property damage of $100,000 or more must be reported by telephone or telegram to the Secretary of Labor. This reporting requirement also applies to accidents involving both Federal and non-Federal employees resulting in fatalities or hospitalization. All of the records previously described are subject to the scrutiny of the Secretary of Labor or his authorized representative such as NIOSH personnel, and includes classified documents where appropriate clearance has been granted.

The third section deals with the organization of the agency's program. It delineates the duties, responsibilities, and qualifications of the agency's designated safety and health official, and recommends establishment of agency safety and health committees at all levels. This section also specifies the responsibilities of the employer and the employee in complying with the provisions of the program. One important responsibility is as follows:

> The head of each agency should ensure that in any evaluation of performance or potential, the excellence or culpable failure of each official in charge of an establishment, supervisory employee or other employee, in the performance of his or her occupational safety and health responsibilities, be taken into consideration in accordance with any applicable rules of the Civil Service Commission or other appropriate authority (9:36458).

This provision forms the basis for disciplinary action to be taken when appropriate corrective action to hazards is not accomplished.

The procedures for conducting inspections and abating indentified hazards are contained in the fourth section. Normal day to day inspection and abatement are the responsibillity of qualified agency personnel unless the safety and health official determines that his personnel should do so. All work places must be inspected at least annually. Qualified safety and health inspectors should take environmental samples and photographs where appropriate. Prior notice of such inspections should not be given except for special circumstances, and then only 24-hour notification should be provided the official in charge of the establishment. The inspector should be accompanied during inspections by the official in charge or his representative along with an employee representative. At the conclusion of the inspection, the inspector must informally advise the official in charge and the employee representative of his findings. The inspector should afford an opportunity for these individuals to provide any pertinent information regarding conditions in the work place. Any employee who believes unsafe or unhealthful conditions exist may request an inspection without fear of recrimination. If the individual is dissatisfied with the findings of a requested inspection, he may contact the Federal Agency Safety Programs Office of the Department of Labor indicating his objections. This office will determine final resolution of the matter. The official in charge of an establishment must be notified of all unsafe and unhealthful conditions discovered by inspection. This notice should include a reference to the standard involved and should fix a reasonable time for correction of the condition. This notice must be posted at, or near each place the condition exists, and must remain posted until the condition is corrected. If the condition exists beyond the prescribed abatement period, the head of the organization should be contacted and appropriate action taken including evaluative measure previously described. The official in charge is then required to develop a plan to ensure correction of the condition. This provision has far reaching impact for the supervisor and the employee. If the supervisor does not ensure abatement of the condition, this may be reflected in his performance evaluation. Similar action could be taken against an employee who refuses to abide by prescribed work practices.

The fifth section covers agency occupational safety and health standards. The major provisions of this section are that agency standards adopted prior to 1 October 1974, which are not OSHA standards may be submitted to the Secretary of Labor for review and recommendations regarding readoption as part of the agency occupational safety and health program. In addition, an agency may adopt any supplementary standard for which no OSHA standard exists, but should provide an opportunity for written comment by all interested parties and should consult with the Secretary of Labor before doing so.

The final section authorizes establishment of Field Federal Safety and Health Councils consisting of representatives of local area Federal agencies and Labor organizations representing employees of local area Federal agencies. The purpose of these councils is to "facilitate the exchange of ideas and information throughout the government with respect to matters of occupational safety and health (9:36463)." Through the use of these councils, Federal agencies may assist each other in complying with OSHA through the exchange of information regarding administration of their programs, particularly abatement of hazards.

As can be seen from the previous discussion, the guidelines for implementing and maintaining an effective occupational safety and health program for Federal employees have a significant impact on normal operations of all Federal agencies. This author has deliberately attempted to retain the wording of the guidelines to preclude misinterpretation. Only the major points, in the author's opinion, have been covered. Those individuals who will be intimately involved in the administration of the program should personally study these guidelines to obtain detailed comprehension of its provisions.

*The Air Force Occupational Safety and Health Program*

The Air Force has attempted to implement its occupational safety and health program over the past two years. In March of 1973, about the same time that GAO was concluding its report on OSHA implementation in the Federal sector AF Regulation 127-12, Air Force Occupational Safety and Health Program was published. This regulation restated the policies of EO 11612 and DODI 5030.52 and declared the Air Force's intent to comply with these directives and the applicable provisions of OSHA. The office of prime responsibility for management of the program is the Air Force Inspection and Safety Center (AFISC). In fulfilling its commitment to comply with OSHA, the regulation indicates that "it is Air Force Policy to use and develop as necessary safety and health standards equal to or better than those promulgated for the private sector (7:5)." Specific responsibilities are delineated for the appropriate Air Staff offices, and the major commands.

At the Air Staff level, AFISC is responsible for establishing policy for implementation of the program, coordinating the actions of other staff agencies in fulfilling their responsibilities, assuring that appropriate staff agencies accomplish a technical review of existing standards to insure compliance with OSHA standards, and incorporating evaluation of OSHA programs in the Air Force Inspection Program. The Surgeon General is responsible for establishing and managing Air Force medical policy regarding OSHA health standards including policies for monitoring harmful agent concentrations at all Air Force installations. The DCS/Systems and Logistics establishes the policy for compliance with OSHA in his areas of responsibility. Specific duties are levied upon the Directorate of Procurement Policy regarding the impact of OSHA on Air Force contracts. The DCS/Research and Development provides the necessary technical and engineering guidance to insure compliance with OSHA standards for development and purchase of new systems and equipment as well as retrofit programs. The DCS/Personnel is responsible for establishing policies for consultation with employees and employee representatives, processing employee complaints, and administering the environmental differential pay plan. The DCS/Programs and Resources establishes the policy implementation of the program within his area of responsibility. Specifically, the Directorate of Civil Engineering is charged with accomplishing a technical review of OSHA standards covering construction, alteration, maintenance and repair of real property and facilities. Additionally, this directorate assures that Air Force construction projects designed or constructed by other agencies comply with OSHA standards. The Directorate of Manpower and Organization will manage organizational and manpower changes deemed necessary to implement the program.

The major command responsibilities are as follows:

1. To comply with established policies
2. To accomplish technical review of OSHA standards as directed
3. To appoint safety as the office of prime responsibility for administrative reporting and recordkeeping
4. To appoint procurement as the office of prime responsibility for matters dealing with Air Force contracts
5. To investigate employee complaints
6. To establish procedures for monitoring concentrations of harmful agents
7. To insure appropriate consultation with employees

Special responsibilities are assigned to the Air Force Logistics and Systems Command consisting of reviewing and revising existing design criteria, military standards, specifications, and technical orders for new and existing systems and equipment to insure that they meet or exceed OSHA standards. Each Air Force activity is also responsible for reviewing their appropriate directives to achieve consistency with OSHA standards; however, DOD and AF standards continue to apply in situations involving unique military requirements. When deviations to OSHA standards are considered necessary, the inconsistency will be factually documented and forwarded through channels to the Air Staff and thence to AFISC.

The reporting and recordkeeping requirements of AFR 127-12 generally follow the OSHA guidelines for Federal employees. Notable exceptions are that reporting requirements do not include occupational injuries or illnesses affecting military personnel, nonappropriated fund employees, foreign nationals outside of the CONUS, and employees paid on a contract or fee basis. Another exception is that AF policy contained in AF regulations 123-11 and 40-771 will be followed in presenting and hearing employee complaints involving occupational safety and health matters.

The remaining portion of the regulation indicates that evaluations of major command and subordinate unit programs will be conducted by AFISC. In addition, evaluations may, with the consent of the Secretary of the Air Force, be conducted by the Department of Labor. Also, the Department of Labor may inspect contractors performing on or off base. Citations issued are a contractor's responsibility except when citations concern government furnished material, facilities or equipment. The final provision dictates inclusion of occupational safety and health matters in existing or separately appointed councils and committees (7:8).

The fact that this regulation was published in March 1973 has two implications. First, if the duties and responsibilities described have in fact been effectively implemented, very few changes should be required to comply with EO 11807 and the new OSHA guidelines. Second, where conflicts exist between AFR 127-12 and the latest guidance, inconsistencies must be resolved to permit standardized implementation throughout the service.

*Recommendations*

The Department of Defense and the Air Force have had comprehensive and effective safety programs for many years. When viewed objectively, OSHA poses no change in the intent of existing programs. There are new and more stringent requirements; however, the emphasis placed on this program must not be ignored. The Air Force has an opportunity to set the example for other Federal agencies and industry as a whole. For example, direct liaison should be established between the Air Force Systems Command and the National Institute for Occupational Safety and Health to facilitate joint use of personnel and facilities in developing criteria for design and development of standards. Liaison should also be established among the Air Training Command, Air University, NIOSH, and the Department of Labor to

establish training programs for inspectors and other individuals charged with carrying out this program. The Air Force should take an active role in developing standards applicable to its operations to preclude any requirement for deviations from OSHA standards.

At the installation level, considerable effort must be expended if effective programs are to be implemented. OSHA must not be buried among the myraid of other agenda items at committees and councils. Minimum representation must include safety, fire protection, and military health officials as well as employee representatives. The offices of Military and Civilian Personnel and the Inspector General should be included when matters pertaining to compliants or ineffective abatement procedures resulting in disciplinary matters are discussed. Explicit instructions regarding abatement procedures must be published if the program is to be effective. A prerequisite to establishment of any program is the availability of the prescribed standards. Although ARF 127-12 states that "Air Force regulations, manuals, pamphlets, and technical orders will be used at all Air Force base/installations for guidance and direction on occupational safety and health matters (7:5)," the Federal guidelines dictate that copies of OSHA and the Executive Order, in addition to the agency's program and guidelines, should be available to employees or their representatives (9:36457). Disparities such as this could result in labor relations problems.

Related problems could arise concerning the standards. Safety inspectors must be knowledgeable concerning the standards and must have the necessary equipment to accomplish their duties as prescribed by NOISH. Engineers designing local contract projects must be familiar with the standards to insure that construction specifications are consistent with OSHA standards. Procurement personnel must also be intimately familiar with the standards to insure that local purchases meet OSHA requirements. These are only a few of the many offices whose personnel must have a working knowledge of OSHA standards. To achieve this degree of expertise, the standards must be available at each installation and procedures for insuring that they are current must be established.

Another area of concern is the abatement process. The correction of unsafe or unhealthful working conditions is the responsibility of the official in charge. This individual is many times hampered by budget restraints or time consuming administrative procedures. If he requires support from another organization, this only adds another complication. Yet upon reinspection, the supervisor's performance evaluation may be affected if the condition continues to exist. On the other hand, the employee has a resonsibility to abide by prescribed safe practices. Failure to comply with these practices could be reflected in his performance evaluation. Additional guidance is needed to determine what action is considered appropriate. Close coordination and active support is required by employee unions to assist in enforcing the program. If the existing Air Force complaint procedures are to be utilized by an individual employee is submitting a complaint involving occupational safety and health matters, local Inspector General and Civilian Personnel Offices will require guidance and training in resolution of these matters.

OSHA must not be allowed to stagnate. The Air Force should take an active role in the development of appropriate standards and must insure that training is provided to safety and health inspectors. Additional guidance must be provided to clarify procedures for abating unsafe and unhealthful conditions and appropriate action that must be taken for failure to correct hazardous conditions and practices.

### *Areas Requiring Additional Research*

The GAO report of March 1973 indicated that OSHA intends to design a model occupational health and safety program for emulation by all Federal agencies (2:55). The guidelines for Federal employees indicates that the Department of Labor will prepare and distribute handbooks to assist Federal Agencies in establishing their programs.

An expansion of this concept could be the design of a model Air Force program based on the mission and size of the organization. Along these same lines, the programs of other Department of Defense component services, as well as approved State programs could be examined to determine methods and procedures that would be beneficial to the Air Force.

### *Summary*

The provision of safe and healthful working condition is the responsibility of every individual in the Department of Defense. To achieve this objective, there must be a viable, effective occupational safety and health program implemented at all echelons. A passive approach of providing the minimum required by regulation is not sufficient. A diligent concerted effort must be made to implement the Air Force policy of meeting or exceeding the standards of the Occupational Safety and Health Act.

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# CHAPTER VIII — ENVIRONMENTAL IMPACT AND ASSESSMENTS

## ENVIRONMENTAL ASSESSMENT AND IMPACT STATEMENTS

By Julius C. Larson, Jr., Capt, USAF

*Introduction*

So far the week hasn't been a total loss. You lean back in your chair and put your feet on the second open drawer and just plain enjoy the sunshine streaming in the open window. You are at last in your thought processes when you hear the raucous sound of the intercom buzzer. It's your boss and he wants to see you right away. You spring alertly to your feet and in a flash you are down the hall and in front of his office. You knock twice. He says "come in" and you stalk confidently into his office. He doesn't even look up from a sheaf of papers in front of him but merely says, "Have a seat, we have some talking to do." He leans back in his chair and begins to talk about the new jet engine test cell you have requested for Any AFB. He mentions the NEPA only by its acronym and goes on to say, "It appears that we need an assessment of the impact of your new test cell on the environment and a statement prepared to formalize your assessment. Civil Engineers require the statement to accompany the request for the test cell to higher headquarters. I'm going to leave this whole business up to you. Feel free to call on me for any help you need." He tosses the sheaf of papers across the desk, you gather them up, pivot sharply and depart his office. As the door closes behind you, several questions come immediately into your mind: Why must an environmental impact statement be submitted? What is NEPA? What must an environmental impact assessment contain? How do you prepare the statement? Why must *I* prepare the statement, why not Civil Engineers? There is one thing for certain at this point in time. During the time you devote to accomplishing the environmental assessment and impact statement, you will probably answer all of your questions. First things first; Why accomplish an environmental impact statement?

### BACKGROUND

*Why Environmental Impact Statements are Necessary*

Recent history of America has shown progress charted as a function of the Gross National Product. Americans have traditionally been proud of their productivity and wealth and affluence in material goods. We have paid the piper, as the saying goes, for the progress we have made. We have: polluted rivers, fouled air by smoke and chemicals, decimated woodlands, land areas strip mined and left barren, and intolerable noise levels (7). Increasingly however, recognition is made that while there are benefits to be derived from a proliferation of material goods, there are also associated costs. While the costs have always been there, they have, for various reasons been deferred (7:1073). Numerous estimates have been made concerning the deferred costs to the environment of our progress in the material goods area. For example, it is estimated that it will cost between 24 and 26 billion dollars over the next five years to do an acceptable job of cleaning up our streams, lakes, rivers, and bays (12:1). While Americans have generally either ignored or otherwise become inured to such things as air and water pollution, increases in the population requiring people to live closer together have forced a re-evaluation of pollution and its effect on the environment. People are becoming less complacent about the quality of their surroundings, the use of the environment, or the manner in which public resources are administered.

Another area of concern to a population rapidly becoming sensitive to the quality of their environment is the fact that the problem of pollution has been a silent intruder that does not always signal its presence until serious damages have been done. Indeed as one author puts it:

> Some of our problems have arisen so gradually, and seemingly so naturally as a part of our accustomed lives, that we have scarcely noticed them until some threshold has been passed. There have been voices we have not heard, signs we have not read. Portents have gone unheeded until attention has been commanded by assaults upon our minds, hearts, and senses (2:22).

In response to the growing concern of Americans for the environment, the three sectors of the Federal government have combined to develop a program to redress the damages that have been done to the environment; your environment; my environment. The programs undertaken have been a decade in developing (9:109).

*Efforts to Develop a National Environmental Policy*

Efforts to establish a national environmental policy go back to 1959 when the Resources and Conservation Act, bill S2549, was proposed (10). The bill required that a national policy on conservation, development, and utilization of natural resources and for other purposes be declared. The bill was a failure, and was followed by S2282, the Ecological Resources and Survey Bill (4). The Ecological Resources and Survey Bill authorized the Secretary of the Interior to conduct studies of national environmental systems in the United States and to make grants and contracts for such studies to be made by universities, museums, botanical gardens, and qualified individuals. It also authorized the Secretary to establish a clearing house for information on ecological problems and studies and to disseminate information about progress in the environmental field. The bill also provided for the setting aside of representative natural environments on Federal lands for scientific study. It too failed. In 1967 a bill similar to the bill that was finally passed was proposed (S2805) but died in the Senate (5).

*The National Environmental Policy Act (NEPA)*

In 1969, The National Environmental Policy Act (NEPA) was passed and became Public Law 91-190 on January 1, 1970. The purpose of the act was to declare a national environmental policy, prevent or eliminate damage to the environment and biosphere, and to establish a Council on Environmental Quality (9:111). The Environmental Quality Council was established by Executive Order 11472, May 29, 1969. Executive Order 11514, *Protection and Enhancement of Environmental*

*Quality* enacted on 5 March 1970 changed the name of the Environmental Quality Council to The Council on Environmental Quality (CEQ) and directed the CEQ to:

> Evaluate existing and proposed policies and activities of the Federal Government directed to the control of pollution and the enhancement of the environment and to accomplish other objectives which affect the quality of the environment (9:118).

Within NEPA, Section 102, subparagraph C (the enforcement provision) directs all agencies of the Federal Government to

> . . . include in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on . . . the environmental impact of the proposed action (9:122).

The NEPA also directs all agencies of the Federal Government to review their current regulations and policies for compliance with the new law. Pursuant to that directive, Headquarters USAF published Air Force Regulation 19-2 dated 22 November 1974 (Environmental Protection) to comply with the intent of NEPA.

Why must an assessment be made of a proposed action that may significantly affect the environment? Public Law and various regulations require all government agencies to assess the effects future programs may have on the environment. It's the law. To summarize:

> The National Environmental Policy Act (NEPA) is the most comprehensive legislative statement of the nation's recently formed commitment to protect the environment. Its language is expansive in setting forth the need to achieve productive harmony between man and nature. The Act requires the government to take account of environmental considerations in all of its actions and establishes the Council on Environmental Quality CEQ and defines its functions (1:v).

It would seem then that NEPA is the cure-all to correct environmental abuses. There are a few shortcomings to the present law but the advantages far outweigh the disadvantages.

### *Criticisms of NEPA*

The scope and generality of the NEPA's mandate threatened its effectiveness. The drafters were aware of the danger, and added an action forcing provision which required all federal agencies to prepare a detailed statement on all actions significantly affecting the quality of the human environment (1:v). While the intentions of the bill are admirable, detractors argue that

> It (the bill) provides for absolutely nothing. It is a statement of principle, but it is a statement of principle that does not lead anywhere. . . . The Congress of the United States and the executive branch of government, recognizing the growing public demand and concern over the environment, have moved to abate the concern, not the pollution (6:67).

**The United States Air Force is undeniably a "Federal activity," so the NEPA provisions extend to any Air Force projects or activities which may significantly affect the quality of the human environment.**

Since the NEPA applies only to Federal agencies, there is considerable debate as to just how much a Federal agency has to be involved before the NEPA applies. For example:

> Cases involving the federal-aid highway program raise all of these issues. Sometimes the interplay of the issues makes the highway cases analytically difficult to distinguish. Federal and state defendants may try first to argue that a project is not 'federal' enough for NEPA to apply. This failing, they may assert that the project is not yet federal enough for NEPA to apply. Finally they may withdraw requests for federal funding and approvals in an attempt to 'defederalize' the project (8:346).

A question naturally arises when you consider the possibility of a small municipality turning down an offer of funds from the Federal Government because of the environmental impact assessment and statement. That question might be: Why would an environmental impact statement give pause for accepting or rejecting federal funds? One reason for this seeming inconsistency in rational behavior might be the difficulty of adequately preparing an environmental impact assessment. The tone of this paper may suggest that only natural resources are subject to the process of wastage through neglect. The environment consists of all of the objects, conditions and processes to which living matter is sensitive and capable of reacting, including changes in the intensity of the stimulus. The environment contains both favorable and unfavorable conditions for man. It has also been established that events taking place far from an existing organism in time and distance may have consequences for that organism because of the interconnected web of cause and effects that tie together the living organisms and minerals that form our biosphere. Assessing the effects and possible effects a proposed course of action or change in policy may have on the environment is a difficult task because of the interconnecting web of cause and effects in space and time. In a recent newspaper article, a group of people in a small suburb applied for federal funds to assist them in constructing a playground for their children. Estimated cost of the project was four thousand dollars. A consulting firm offered to do the environmental impact statement for thirty thousand dollars (3).

In addition to the complexities of performing an environmental assessment, use of federal funds before NEPA involved frequent federal participation in local decision making through the issuance of federal guidelines as to how the work was to be done, etc. The NEPA enlarges the scope of federal participation in local projects and is therefore avoided whenever possible by "defederalization" of the projects. The playground example cited above may give the impression that environmental impact statements are difficult if not impossible to submit (judging by the high dollar cost of the cited estimate). Consider if you will, the salient points that environmental impact statements must cover.

## ENVIRONMENTAL IMPACT ASSESSMENTS AND STATEMENTS

### *Contents of the Environmental Impact Statement*

**The following points are to be covered:**

**(i) A description of the proposed action including information and technical data adequate**

to permit a careful assessment of environmental impact by commenting agencies. Where relevant, maps should be provided.

(ii) The probable impact of the proposed action on the environment, including impact on ecological systems such as wildlife, fish, and marine life. Both primary and secondary significant consequences for the environment should be included in the analysis. For example, the implications, if any, of the action for population distribution or concentration should be estimated and an assessment made of the effect of any possible change in population patterns upon the resource base, including land use, water, and public services, of the area in question.

(iii) Any probable adverse environmental effects which cannot be avoided (such as water or air pollution, undesirable land use patterns, damage to life systems, urban congestion, threats to health or other consequences adverse to the environmental goals set out in section 101(b) or the Act).

(iv) Alternatives to the proposed action (section 102 (2) (D) of the Act requires the responsible agency to 'study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resoures'). A rigorous exploration and objective evaluation of alternative actions that might avoid some or all of the adverse environmental effects is essential. Sufficient analysis of such alternatives and their costs and impact on the environment should accompany the proposed action through the agency to identify the extent to which the action curtails the range of beneficial uses of the environment.

(v) Where appropriate, a discussion of problems and objections raised by other Federal, State and local agencies and by private organizations and individuals in the review process and the disposition of the issues involved (9:167-168).

To be acceptable, all of the foregoing requirements must be considered in assessing the effect of a particular program or policy change on the environment; that is to say that the contents of an environmental impact statement are adequately defined in the body of the NEPA.

***Preparation of Environmental Impact Statements***

It is beyond the scope of this paper to enumerate all of the various steps in the submission of the environmental impact statement. Submission of statements that apply to Air Force actions is covered in detail in Air Force Regulation (AFR) 19-2 (Environmental Assessments and Statements).

Air Force Regulation 19-2, Attachment 1 entitled "Air Force Guidance on Major Actions, Significantly Affecting the Quality of the Human Environment," adequately describes a number of factors to be considered when deciding whether or not an environmental impact assessment is necessary. In the submission of environmental impact statements, time is of the essence because:

> Commands and separate operating agencies, must insure that a decision is not made until the environmental consequences of the proposed action have been assessed (11:6).

In other words, a program or plan may be ready for implementation, but if an environmental impact assessment has not been made, the decision to implement the program cannot be made; it's as simple as that. The environmental assessment can act as a sounding board for public attitudes toward a proposed program or action. If the proposed program is controversial in nature, then the environmental assessment can sum up or synthesize the nature of the resistance to the proposed action.

If the environmental assessment reveals the proposed action will generate considerable controversy, and in fact there is a chance the proposed action may not be approved of, the earlier in the program this is determined, the better off the planners will be.

> With respect to environmental controversy, the proponent of the project or action should attempt to determine the attitudes of the public and private sectors of the community toward the action at the earliest possible moment in the planning process (11:6).

It would be costly and unwise to initiate a far-reaching program only to have it stall because environmental assessments had not been made.

Attachment 2, AFR 19-2 provides a cookbook method for the mechanics of completing an environmental assessment and many situations are listed that would require the submission of an environmental statement. It should be noted that the definition "effect on the environment" does not have a good or bad connotation because:

> The proponent must evaluate the nature and degree of all effects on the environment. These may be significant even though the net environmental effect of the proposed action will be beneficial (11:6).

In addition, Attachment 1 to AFR 19-2 should be read carefully to enhance your appreciation of the scope of the factors and situations that require submission of impact statements. For example; actions that overburden existing or proposed public service facilities and utilities, actions that may impact private facilities and operations (such as local housing, transportation and recreation), and actions that may affect the existing character or future development of an area all require an environmental impact statement.

***Stages of Environmental Impact Statement Development***

Environmental impact statements are developed in three stages (11:1). The first stage is the Candidate Environmental Statement. The Candidate Environmental Statement is generally prepared by upgrading the environmental assessment with the inclusion of more detailed analysis. Candidate Environmental Statements are submitted to Headquarters United States Air Force (Directorate of Civil Engineering) by the major command or separate operating agency. Ideally only a change in title is necessary to advance the Candidate Statement to the next stage, The Draft Environmental Statement.

The Draft Environmental Statement explains " . . . an action considered by the HQ USAF Environmental Protection Committee established under AFR 19-1 and

designated as having a significant effect on the environment . . . (11:1)." It is submitted by the Secretary of the Air Force to the Council on Environmental Quality (CEQ) and to other agencies and interested parties for comments.

The third stage of the process results in a Final Environmental Statement. The Final Statement is submitted by the Secretary of the Air Force to the CEQ and combines all pertinent comments from other Federal agencies and interested parties and the responses to these comments. It is used by the decision makers as one of the factors in reaching a decision to proceed with an action (11:1).

### *Legal Aspects of NEPA*

It would seem as if only the Legislative and Executive Departments are on the forefront of the drive for a clean environment. While the initial legislation efforts were accomplished by the Legislative and Executive Branches, the Judicial Branch is beginning to get involved in the movement to protect the environment.

The legal system in the United States is founded on principles of codified law and legal precedence. In the short history of the NEPA, several landmark cases have begun to establish precedence with respect to NEPA. For a summary of judicial decisions involving the National Policy Act through December 31, 1971, read "Environmental Law," by Arnold W. Reitze, Jr. (9:187-193).

One of the significant outgrowths of the NEPA is the increased willingness and ability of citizen action groups to confront Federal agencies and departments through the courts. Prior to NEPA, there were many court cases involving single litigants and large industrial firms. With respect to legal questions that have been raised in our court system it can be said that:

> . . . many of the encroachments of a modern society on an individual's right to a quality environment are gradual, subtle, and unforeseen. They have not often, at least until recently, generated litigation. Moreover, when an individual does decide to exert a legal claim to environmental quality, he may find he has taken on the legal and economic resources of an entire industry (7:10).

The amount of legislative, executive and judicial interest that has been focused on environmental problems makes one point abundantly clear. The Federal government will become increasingly involved in the struggle to maintain acceptable levels of environmental quality. The interest generated by a citizen concerned with environmental quality is manifesting itself by changing the traditional role of government in the management of environmental affairs. Probably the main reason for this change in governmental roles resulted from increasing changes in our environment, especially those that are harmful or degrade the quality of the environment. The increased visibility over cause and effects is the key to improved management of the environment. As an increasing tide of public opinion has made itself felt, the magnitude of the problems confronting society are being brought to the surface. It has become clear that only government has the scope and resources to take effective action.

The role of the government is inescapable, not because the individual property owner, farmer, business firm or industry cannot manage affairs properly, but that they have no direct influence over another's management.

> One man's mistake or economy is another man's cost, sometimes at a great distance. The city man's wastes go into storm and sanitary sewers and become trash for the dump. One city's disposal and waste treatment, when inadequate, becomes a cost to the next downstream or downwind city. One farmer's erosion is his downslope neighbor's siltation. Factories build tall smokestacks to carry off their foul and sometimes dangerous effluents, and the sulphur becomes corroding acid in another town and turns soil sour dozens of miles away (2:27).

It can be said that all departments, branches and agencies in the Federal government are involved in the quest for a high quality environment both for the current generation and those to follow. An attempt on a very wide scale is being made to clear up the debts we have created by taking liberties with the environment to satisfy our desires for material goods.

## CONCLUSION

Environmental impact assessments are the result of increased awareness of the gradually creeping effects of changes to the environment. No longer can wanton disregard for the environment be tolerated in the Federal Government decision making process. Environmental impact assessments force planners to consider the environment during the decision making process. The National Environmental Policy Act (NEPA) is then a form of contract with the Federal Government that recognizes two realities.

The Federal Government is the only organization in the United States that has a power base large enough to adquately protect the environment, and that the Federal Government must act as the caretaker of the environment and protect it for future generations. The actual preparation of the environmental impact assessment is an interdisciplinary function, but may be supervised and coordinated by one individual, the preparer. The responsibility for the assessment accrues to the Commander of the organization planning the action, but be advised that he may not prepare the assessment himself, but may "farm it out" to his staff. You, the reader may well be the staff member selected. Prepare yourself by reading AFR 19-2 and familiarize yourself with the types of actions that necessitate submission of an environmental assessment. The earlier in the program that an assessment is made, the fewer the unwelcome surprises that may crop up at later stages of the planning process. Now that you have been exposed to the environmental assessment and impact statement you will be in a little better shape to handle that special project you may one day get, the accomplishment of an environmental impact statement. Think positively about it; the environmental assessment and impact statement you accomplish is for your own good as much as it is for the good of the society, the environment and future generations.

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# CHAPTER IX — COSTS AND BENEFITS

## APPLICATIONS OF MODELS TO ENVIRONMENTAL BENEFIT—COST ANALYSES

By William R. Harris, Capt, USAF

*Introduction*

The purpose of this paper is to examine the application of models to benefit-cost analyses used to evaluate alternative programs for the control of environmental pollution. General concepts of benefit-cost analysis and models and situational factors applicable to environmental pollution will be presented to provide a framework for study of existing environmental models. A review of the literature revealed that a generic model which can be used to perform benefit-cost analyses of environmental programs does not exist at the present time. The models found in the literature are used to provide specific information about particular aspects of environmental control. In some cases, one model can provide the information a decision maker needs to attack a pollution problem. In other cases, a decision maker must use an array of different models to give him the information he requires. Example models will be presented after a discussion of concepts and situational factors. The approach to the models will be descriptive rather than critical with the hope of providing sufficient background information for the reader to form his own criticisms of the models. Perhaps improvements in the use of models and benefit-cost analyses can be found which will resolve some of the dilemmas evident in the environmental arena.

### CONCEPTS OF BENEFIT-COST ANALYSIS

Benefit-cost analysis is a systematic appraisal of all the benefits and costs of a proposed course of action. In an economic context, a benefit represents the value of a goods or service to a consumer. Similarly, a cost is a foregone benefit (14:13). Benefit-cost analysis is a common approach to deciding how to allocate scarce resources among alternative programs involving expenditures of government funds. In public projects, costs are not always borne by the parties who reap the benefits. By totaling all benefits and costs and computing a benefit-cost ratio

$$BCR = \frac{AW}{AC}$$

where BCR = benefit-cost ratio,
AW = annual worth of benefits to those receiving benefits,
AC = annual cost of the project to those paying the costs,

a decision-maker can determine the ratio of the benefits returned to the public to the cost borne by the public for a particular alternative (17:12). A project having a benefit-cost ratio less than one is not economically justified. Care must be exercised in the interpretation of a benefit-cost ratio. A proposed project may have several different values of the benefit-cost ratio depending on whether certain adverse items are added to costs or subtracted from benefits (4:138).

Measurements of costs and benefits for public programs, even in a gross sense, can be difficult. The economic definition of a cost as a foregone benefit requires that the following steps be taken to measure costs (10:3):

1. Estimate the value of the labor, materials, facilities, and other resources required to develop, implement, operate, and dispose of a proposed program.
2. Identify the principal alternative uses of the resources needed for the proposed program.
3. Estimate the value of the benefits from the alternative uses which will be foregone if the proposed program is selected.

However, the usual approach to measuring costs is to estimate the dollar expenditures required to obtain the resources needed for a proposed program. The use of a dollar measurement for costs, in effect, accomplishes all three steps at once. The assumption in this approach is that the value of the benefits obtained from alternative uses of the resources is adequately measured in dollar terms. When resource prices are determined in a free market economy, such an assumption is valid because the market prices reflect the value placed on the resources by alternative users. The assumption that dollar expenditures reflect the value of foregone benefits does not hold for those resources for which prices are not determined in a competitive market. One example of this type of resource is the trained government employee, particularly a military member, who is subject to frequent job rotation to meet requirements other than those directly related to mission. Pay and allowances for the employee in one duty assignment may not be equivalent to his value in a different assignment (10:2-3).

In public projects, it is often difficult to measure social benefits and social costs in terms of dollar expenditures. Recognizing the lack of social measures, Bell stated,

> What we need, in effect, is a system of Social Accounts which would broaden our concept of costs and benefits, and put economic accounting into a broader framework (to) move toward measurement of the utilization of human resources in our social information areas: (1) the measurement of social costs and net returns of innovations, (2) the measurement of social ills . . . , (3) the creation of 'performance budgets' in areas of defined social needs . . . , and (4) indicators of economic opportunity and social mobility (1).

Several approaches have been used to overcome the inability to measure the full range of costs and benefits in terms of dollar expenditures when preparing a benefit-cost analysis. One method is to treat the costs or benefits which cannot be measured in dollars as externalities, or irreducibles, to be dealt with according to the best judgment of the decision maker (4:17,484).

Another method of dealing with the inability to measure benefits quantitatively is to conduct a cost-effectiveness analysis. The measure of benefits is replaced with a measure of effectiveness, or how well a proposed alternative accomplishes a specific objective. Use of cost-effectiveness analysis requires several

assumptions (12:2):

1. The right objective has been specified.
2. A satisfactory way of measuring performance and evaluating effectiveness has been found.
3. All relevant alternatives have been found.
4. The influence of other non-dollar costs is negligible.

In situations where multiple objectives are specified, or where benefits and costs among various alternatives are not directly comparable, a tradeoff analysis is conducted to select superior alternatives given the assumptions relative to each objective. The decision maker is placed in a better position to understand the relevant alternatives and the interactions among them by having some measure of the costs and relative effectiveness of each alternative.

It is important to recognize that the types of analyses discussed so far have limitations. An analysis is usually incomplete. Time and money are not always available in sufficient quantities to allow inclusion of every relevant factor in an analysis. Most analyses deal with static measures which in reality may behave in a dynamic fashion. Dollar costs alone can change rapidly during the period of an analysis because of inflation.

Even if sufficient time and money were available, many relevant factors are highly intangible and will have to be treated as irreducibles. Other factors are omitted because their relevance is not recognized. Measures of effectiveness are often approximate for many of the relevant factors which are identified.

The time horizon which public programs cover is often so broad that considerable uncertainty exists as to the course of future events. It is possible to forecast general trends with a fair degree of accuracy, but it is nearly impossible to predict a single future outcome in the terms required for an optimal decision in the present.

Quade (12:14) says that "the essence of the cost-effectiveness method is to construct and operate within a 'model'—an idealization of the situation appropriate to the problem." The role of the model is to predict the costs incurred by each alternative and the benefits, or effectiveness, obtained from each alternative. The following section will describe some of the basic concepts of models.

## MODELS

Maki and Thompson (9:2-6) identify four steps which comprise the process of building a model.

1. Perform initial study of a real world problem.
2. Construct a real model based on idealizations and approximations which eliminate unnecessary information and simplify the remaining information.
3. Construct a mathematical model which expresses the real model in symbolic terms, and study the model using appropriate mathematical ideas and techniques.
4. Compare the results predicted by the mathematical model with the real world.

The real model constructed in Step 2 is still in the context of the "real world", but simplifications may have made the situation unrealistic. For example, an unrealistic situation can be created by choosing to treat a certain factor in a given modeling situation as an irreducible when, in fact, it has an important effect on the situation.

The mathematical model constructed in Step 3 is expressed in symbolic terms. The usefulness of the mathematical model depends on the success the model builder has in identifying his specific model with the real world. The purpose of studying the model is to produce new information about the situation which the model represents. A comparison of the results of the model with the real world is made to determine if the model accounts for everything observed in the real world and if the predictions of the model correspond to what actually happens in the real world. In the cases where discrepancies exist,, Maki and Thompson (9:3) propose that the following questions be answered;

1. Was something significant omitted in the step from the real world to the real model?
2. Does the mathematical model adequately represent the real model?
3. Does the mathematical model produce results which are not observed in the real world?
4. Is there an error in the mathematical model?

Once these questions are answered, the modeling process can be repeated until a satisfactory model is found.

Certain concepts or conditions of a real model may be difficult or nearly impossible to quantify. As a result, conclusions based on a mathematical model may not be applicable to the real model or to the real world. It is sometimes possible to draw conclusions from the real model or from a combination real model-mathematical model. A computer simulation model is an example of a combination model. If a combination model is used, it is important to distinguish between the conclusions drawn from the mathematical part of the model and the conclusions drawn from the real part of the model.

Interpretation of model results must take into account the nature of a model; that is, the model is a representation of reality and not reality itself. Two steps in the modeling process are especially important. First, the construction of a mathematical model is a unique process for each real world situation studied. However, more than one model could provide satisfactory results for a given situation. A method of choosing the best model would then be required. In dealing with complex problems, it may be necessary to use several models, each one providing information about one particular part of a problem. Second, interpretation of model results and application of the information obtained from the results to the real world must be tempered with judgment based on the recognition of the limitations of a specific model.

Before describing specific models which have been applied to benefit-cost analyses of environmental pollution problems, the following section will describe situational factors which influence the use of benefit-cost analysis in the area of environmental pollution control.

## SITUATIONAL FACTORS

Environmental pollution is not cheap. Resources allocated to it have to compete with other needs of society, and it is therefore important that they are used most efficiently (2:iv).

> Problems if the environment, particularly those of air pollution, are serious enough to justify government intervention (8:19).
>
> If one consideres any activity and tries to measure either the average or the marginal

total—i.e., social—damage it does, he will find that the damage depends upon the overall context in which the activity takes place. It is determined by the kind of activity involved,the amount of the activity that is carried out, the amount of the same kind of activity that is carried out by other users, the number and extent of other activities in the system which this activity can damage, how crowded for frequent use is, and the assimilative capacity of the common medium. In other words,the particular amount of blame or praise to be assessed is not intrinsic to any definable characteristics of each user, taken one at a time. Damages are highly dependent upon particular situations (13:80).

The purpose of this section is to establish a basic framework upon which models related to environmental pollution control can be examined. The quotes given above indicate that pollution control is expensive, requires government intervention, and is highly complex. The focus of this section is on the situational nature of pollution problems. Costs are mentioned to emphasize the point that pollution control uses resources resulting in foregone benefits that must be included in an analysis of pollution problems. The presence of the government in the environmental control arena adds a dimension of public policy goals to the analysis of pollution abatement and control programs.

Rothenberg (13:71-95) provides an expanded discussion of the situational nature of environmental pollution which can help define the types of situations that environemntal control models must address. Defining air, water, and land as common use media, he describes inter-user interference as the decline in quality of a medium resulting from the condition in which use of the medium exceeds its assimilative capacity to disperse, dilute, or purify the potential interference released by the users into the medium. He then establishes two extreme classifications to describe the types of user interference which occur in a system. On one extreme is pure congestion, in which each user generates the same amount of interference per unit of activity and suffers equally from the total amount of interference generated in the system. A highway traffic jam is an example of pure congestion if only the motorists directly involved in the traffic jam are considered. On the other extreme is pure pollution, in which users generate different amounts of inter-user interference. In addition, the generators of interference do not suffer themselves. The sufferers are users who have not generated the interference. An example of pure pollution is the suffering of a downstream user from the pollution caused by an upstream user who does not suffer from his own pollution acitvities. In real life, most pollution situations are somewhere in between these extremes. Residents of large cities suffer from the carbon monoxide pollution caused by masses of automobiles jammed on city freeways. Upstream polluters are downstream from other users who add pollutants to a stream, so they also suffer pollution damage.

For a particular pollution situation which falls between the extreme classifications of pure congestion and pure pollution, there are two groups of users: polluters and pollutees. Two factors, however, make the identification of these groups difficult. First, inter-user interference, or pollution, is usually not intentional. It arises from attempts of users to optimize some other type of activity in which they engage. Second, there is usually not a one-to-one relationship between polluter and pollutee. In general, the pattern found is many polluters-many pollutees (13:77). Third, pollutees can also be polluters within a particular environmental situation.

Rothenberg (13:77-78) also classifies the type of use as benign or toxic. These classifications, however, are not absolute. A benign use can become toxic if the level of actvity exceeds the assimilative capacity of a medium because of crowding or too frequent use. The pollutants added to the water in a swimming pool by one swimmer can be considered benign. If too many swimmers crowd the pool, the pollutants added may cause the swimming pool water to become toxic. A potentially toxic use may be benign in a given situation. For example, an upstream user who adds heat to a river does not pollute the water for a downstream user who only wants to dump waste materials into the river.

Another point Rothenberg (13:78) discusses related to the moral interpretations of benign and toxic uses. The question of who came first is difficult to deal with. If a user is in operation first with no intention of causing pollution, who is responsible when another user comes on the scene and suffers pollution damage? An answer to this question could help resolve the problems caused by airport noise in newly developed areas surrounding existing airports.

Rothenberg (13:80) concludes that no given use of an environmental medium has intrinsic potential for causing pollution damage. Any intervention in a given situation to alter the total system damage will involve real resource costs. To be warrented, every intervention designed to upgrade the environment must produce benefits at least equal to the cost incurred by the intervention. He further states that,

> The goal of public policy, then, is not to 'minimize' pollution, but to 'optimize' pollution. What we are looking for is not the smallest amount of pollution technically achievable, but the most appropriate amount, the amount that gives us the best compromise between the use of our recources for the production of other goods and services and the use of our resources to produce environmental quality. . . . Solving the problem of environmental degradation is extraordinarily difficult. It is even more difficult because we are coming to realize that the problem does not arise because of villainy, nor does the solution consist in a desire for a total upgrading of the environment (13:81, 94).

It should be noted that the word optimize in the above quote is used in an economic context rather than a mathematical context. The distrinction will become more apparent in the next section dealing with environmental models.

## ENVIRONMENTAL MODELS

The previous sections have provided background information on the general concepts of benefit-cost analysis and modeling and on the situational factors which affect analyses and modeling efforts. This section will present a few examples of models that have been used to aid decision makers in selecting alternative programs for controlling environmental pollution. The approach taken in this section is, for the most part, descriptive. It is hoped that the previous discussions of

concepts and situtational factors have provided sufficient information for the reader to form his own criticism of each model. Perhaps he can find an improvement which will assist in further applications of models to benefit-cost analyses of environmental problems.

*A Benefit-Cost Analysis of Air Pollution Abatement*

Lave (8:19-37) prepared a benefit-cost analysis of a nationwide air pollution abatement program to illustrate the economic feasibility of an air pollution abatement program and the limitations of using a benefit-cost approach to conduct the analysis. Although Lave did not use mathematical models, his aritcle is included for two reasons: To show the general format of a benefit-cost analysis; and to give an indication of where and how models could be used to quantify some of the irreducibles in an analysis.

The basic approach followed by Lave was to systematically search for all the effects of a project and classify them as benefits or costs. He classifed costs as follows:

1. Direct costs—Cost of new capital equipment, cost of modifying existing equipment, cost of operating pollution abatement equipment.
2. Indirect costs—capital losses resulting from shutdowns because of inability to finance new or modified equipment, temporary unemployment, losses of tax revenues.

Benefits were classified as:

1. Direct benefits—health improvements, reduces cleaning costs, longer materials lives.
2. Indirect benefits—better quality of life.

Lave recognized the difficulty of quantifying the costs and benefits and identified. He also concluded that a benefit-cost analysis tends to underestimate the benefits of the proposed project and overestimate the costs. The costs he found were generally based on current abatement technology rather than on the costs of meeting specified pollution standards by developing the appropriate technology.

The benefits he was able to quantify were included in his analysis. The benefits he was not able to quanitfy were omitted. The greatest difficulty he cited was the lack of a clear relationship between the quantity of pollution abatement applied and the quantity of benefits obtained. Lave used figures from other studies to estimate the improvements in plant, animal, and human health, the reductions in cleaning bills that should be obtained, and the increases in the useful lives of various materials to obtain estimates of the benefits of a nationwide reduction in air pollution levels of 50 percent. The overall results of his benefit-cost analysis showed that the annual costs of air pollution abatement for the nation would be $3.5 billion per year in 1976, increasing to $6 billion per year by 1985. He was unable to find defensible figures for the savings in cleaning costs, but he did estimate the benefits of improved health to be worth approximately $7 billion per year in 1971. Therefore, on a benefit-cost basis, he concluded that pollution abatement should be carried out.

The next section describes a method of choosing among alternatives for controlling air pollution using mathematical and simulation models.

***A Tradeoff Model For Selecting and Evaluating Regional Air Quality Control Strategies***

Mikolowsky, Biglow, Geoller, and Ives (11) developed a model called Tradeoff as part of the San Diego Clean Air Project prepared by the RAND Corporation. Tradeoff was designed to evaluate laternative strategies for meeting regional air quality standards, select minimum total cost strategies, and analyze the sensitivity of the tradeoff model to certain assumptions. The name of the model was taken from the type of analysis described previously, tradeoff analysis, in which benefits of an alternative are replaced by a measure of effectiveness. In this case, the air quality standards provided the means of measuring effectiveness. One of the inputs to the tradeoff model was the air quality goal, which in turn was computed by another model. This discussion will focus on the cost estimating portion of the model.

Three strategy components were included in the tradeoff model.

1. Fixed source controls
2. Automobile antipollution devices and maintenance policies
3. Transportation management controls

The cost and effectiveness of fixed source controls and various mixtures of automobile antipollution devices and maintenance policies were computed by separate models and provided as inputs to Tradeoff.

Transportation management controls included in the following:

1. Imposing a mileage surcharge in the form of a tax or rationing plan.
2. Inducing changes in the amount of carpooling which occurred.
3. Improving the bus system.
4. Changing travel times by changing the level of highway congestion.

A subroutine within Tradeoff was used to estimate the effects on air quality levels of different transportation management strategies. The loss of mobility experienced as a result of the transportation management strategies was estimated by means of a social cost of foregone travel. The cost of foregone travel was determined by multiplying the cost per foregone trip times the annual number of trips foregone. The cost per foregone trip was an estimate of the social value of a trip in excess of the cost of the trip. The model determined the annual number of trips foregone under a given strategy.

Tradeoff required the following user inputs before operation could begin:

1. Air quality standard constraint, expressed as a do-not-exceed level of allowable emissions
2. Dollar value of a trip foregone
3. Area and population served by the bus system
4. A specific fixed source control strategy and associated annualized costs

Annualized costs included amortization of capital investments using a capital recovery factor and annual operating costs. Additional inputs were added from the other models previously mentioned. Tradeoff minimized the following objective function:

$$\text{MIN } C_T = C_x + C_r + C_m + C_s$$

where
$C_T$ = total annualized cost of an overall strategy
$C_x$ = annualized cost of fixed source controls
$C_r$ = annualized cost of automobile an-

tipollution devices (installation and operation)

$C_m$ = annualized cost of transportation management controls

$C_s$ = annualized social cost of foregone travel

All components of the objective function were provided as inputs to the model except $C_m$. The cost of transportation management control was computed by a Tradeoff subroutine as follows:

$$C_m = \max(C_b, R_b + C_d) - C_b^N$$

where

$C_b$ = annualized cost of the bus system strategy

$R_b$ = annualized revenue from the bus system strategy

$C_d$ = annualized costs to motorist of transportation management surcharges

$C_b^N$ = annualized costs of the existing bus system

The tradeoff model examined different combinations of the three strategy components and identified the best strategy as the one which met the desired air quality standards at the minimum value of the objective function.

Tradeoff possessed two additional features which were helpful. A sensitivity analysis could be conducted by performing repeat runs for different values of a specific parameter to determine the effect on the model of uncertainties in the estimation of that parameter. In addition, a complete strategy could be specified, and the model would determine whether or not the strategy met the standards and would provide as output the amount of emissions produced by the strategy and the maximum pollutant concentration expected. The capabilities allowed by these two features helped overcome some of the deficiencies of cost-based analyses noted earlier. A sensitivity analysis could help resolve uncertainties about the accuracy of a cost estimate if the model were insensitive to changes of that particular cost parameter. On the other hand, additional time and expense could be justified to estimate more closely a cost parameter which had a relatively large effect on the model. A decision maker could use the strategy elvauation feature of the tradeoff model to determine probable outcomes in situations where he was constrained by policy or was unable to include irreducibles in the model.

The tradeoff model has been used successfully in San Diego and has been transferred to other regions. It has demonstrated the following favorable characteristics:

1. Short run time.
2. Flexibility in the use of alternative objective functions, constraints, and technical assumptions.
3. Transferability to other air pollution situations.

***The Delaware Estuary Comprehensive Study***

**The study of the Delaware Estuary, started in 1961 by the Federal Water Pollution Control Association and various state and local agencies, is an excellent example of the proper use of analytical techniques and economic analysis procedures to aid decision makers in choosing alternative courses of action. A report by Smith and Morris (15) provided the information contained in the following paragraphs.**

The study was undertaken to define controls for water pollution to achieve a desired water-use goal in an optimal fashion. Models were constructed to predict cause and effect relationships in the physical environment and to establish potential pollution control programs based on different methods of cost allocation. Water-use goals were established by a technical survey and were specified as five different objective sets based on the desired water quality level in each set. Objective Set V specified maintenance of the existing water quality level, while objective Set I specified the maximum water quality level that could be attained under the available technology. Benefits were quantified to the maximum extent possible, but a model of benefits was determined to be beyond the state-of-the-art existing at that time.

The estuary was divided into 30 separate sections to account for the different physical characteristics of the estuary, such as width, depth, and tidal flow, and the different numbers and types of users in each section. The physical model was constructed to predict the level of dissolved oxygen (DO) in each section of the estuary. The alternative goals were then specified in terms of DO. The details of the physical model are not as important here as are the models used to select the best method of cost allocation.

The purpose of the cost allocation model was to determine how the total allowable waste load (biochemical oxygen demand, DOB) under a specific objective set was to be allocated among the users in a particular section of the estuary. It was felt unwise to require only the largest users to treat their wastes since no recognition would be given to the relative costs among the users of removing pollutants. On the other hand, it was deemed unfair to require only the users with efficient treatment methods to remove their waste load from the estuatry. However, cost of treatment was considered to be an important objective because:

1. The type of control used to conduct a pollution control program could be based on the criteria provided by a range of costs for achieving a particular objective set.
2. The costs of attaining different objective sets could be used to select the final objective set to be used as a water quality goal.

Three cost allocation models were established. Each had the same objective function and constraint equation.

$$\text{MIN} \quad C_k(f_k)$$

subject to:

$$\sum_{j=1}^{N} A_{i,j} f_i \geq B_i \qquad i = 1, 2, 3, \ldots N$$

$$\text{where:} \quad f_j = \sum_{k \in j} f_k$$

$$0 \leq f_k \leq U_k; \qquad k = 1, 2, 3, \ldots M$$

and, $C_k(f_k)$ = the cost function for each source k in dollars

$f_k$ = the additional removal of waste load from each source, summed over the proper sources in each section j to yield $f_j$, the input section waste load removal in kg/day

$A_{i,j}$ = **the results of the physical model describing the relationship between the transformation of a waste load input in any section j of the estuary**

to the stream quality output in any section i (mg/l/kg/day)

$B_i$ = the DO increment required in output section i (mg/l)

$U_K$ = the maximum waste load that can be removed for source k in kg/day

($k \in j$ refers to the sources k that are in section j)

Although the objective function for each cost allocation model was mathematically equivalent, the additional constraints, if any, added to each model produced different results. The details for each cost model are described in the following paragraphs.

*The Cost-Minimization Cost-Allocation Model.*

This model was formulated as a linear programming model with upper bound constraints. No additional constraints were added to the model described earlier. The existing constraints insured that the desired quality was met and that each source treated no less waste than it did at the begininig of the problem and no more than its maximum capability. The result provided the least cost of achieving DO goals for all sources in the estuary region. This model, in effect, required the sources having the least costly treatment method to perform the bulk of the waste load treatment.

*The Uniform Treatment Cost Allocation Model.*

Additional constraints were added to the basic cost allocation model to require each source on the estuary to remove an equal percentage of BOD from its wastes before discharge into the estuary. The additional constraint required that

$$f_k = \begin{cases} (S - P_k)\, T_k & \text{for } P_k < S \\ 0 & \text{for } P_k \geq S \end{cases}$$

where

$P_k$ = current percent removal for each source k

$T_k$ = raw waste load produced by source k (kg/day)

$S$ = the uniform percent removal

Thus, it was necessary to find the treatment level required to satisfy the DO objective, However, the objective function, by minimizing cost, established S at the minimum value which would still satisfy $B_j$. Smith and Morris (15:1640) pointed out that the uniform treatment method was inefficient because a large surplus of DO could exist in non-critical areas. In addition, the added constraints meant that the uniform treatment model would never be better than the cost minimization model and, in most cases, would be more costly.

*The Zoned-Optimization Cost Allocation Model.*

This model was a combination of the two previous models which established uniform treatment levels within zones established along the estuary and then allowed for tradeoffs in costs to be made among the zones. The constraint was changed as follows:

For each zone z: z = 1, 2, 3, D

$$f_k = \begin{cases} (S_z - P_k)\, T_k & \text{for } P_k < S_z \\ 0 & \text{for } P_k \geq S_z \end{cases}$$

for $k \in j$ (the appropriate sources within each section)

$j \in z$ (the appropriate sections within each zone)

Structured in this fashion, the model allowed a set of treatment levels within the zones that provided the minimum costs of treatment along the entire estuary. In addition, the constraint allowed zones to be constructed on bases other than geography. For example, identical types of users could be grouped within the same zone and assigned identical treatment levels. The results of this model were found to be between the results of the other two models.

The analysts were unable to quantify all the benefits resulting from controls established under each objective set. However, they were able to establish reliable estimates of benefits accruing to fisheries and to recreational uses. These estimates were based on historical data and were obtained without using models.

Benefit-cost ratios were computed for each of the five objective sets plus an additional objective set established between Sets II and III by the Delaware River Basin Commission (DRBC). Generally, the ratios increased from Set I to Set III, then decreased for Set IV and Set V. The authors concluded that "as ever more stringent quality goals are specified, costs increase tremendously while benefits tend to level off at a maximum value plateau (15:1645)." Figure 1, taken from Smith and Morris (15:1644), shows the results of the benefit and cost analyses for each objective set. Table 1 summarized the benefit-cost ratios discussed earlier (15:1645).

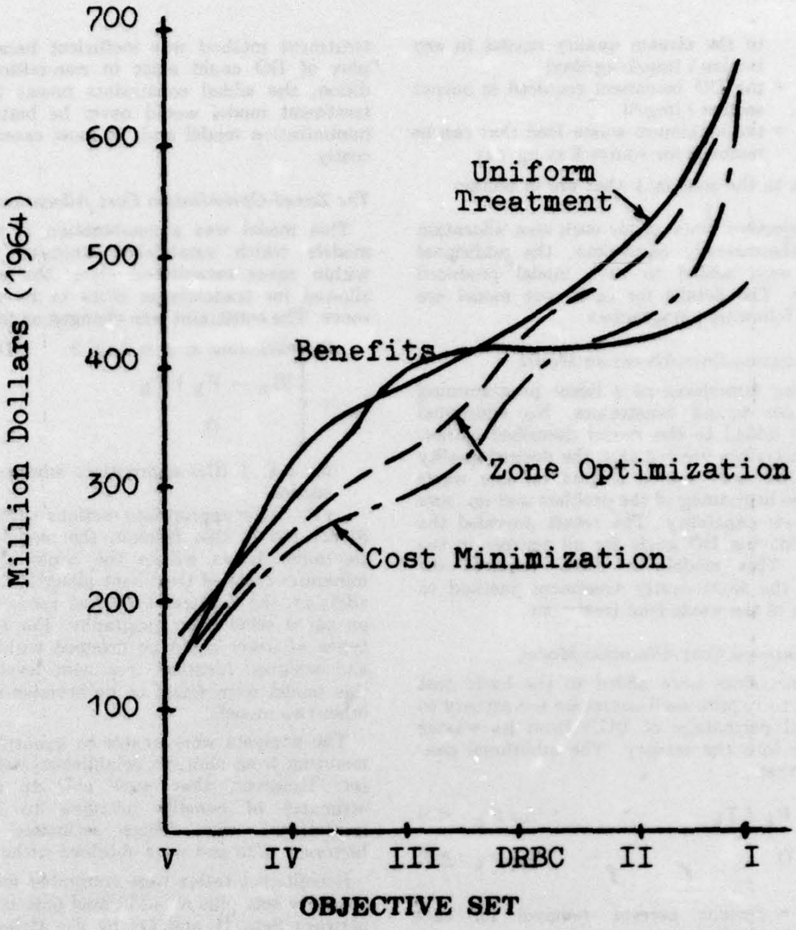


**Figure 1. Graphical Results of the Three Cost Allocation Models and Estimated Benefits.**

**TABLE 1**
**Total Benefit-Cost Ratio**

| Objective Set | Cost Minimization Model | Uniform Treatment Model | Zoned Optimization Model |
|---|---|---|---|
| I | .69 | .69 | .69 |
| II | .97 | .83 | .85 |
| DRBC | 1.09 | .96 | .98 |
| III | 1.39 | 1.05 | 1.24 |
| IV | 1.19 | .89 | 1.11 |
| V | 1.16 | 1.16 | 1.16 |

In 1967, the decision makers chose the DRBC objective set as the goal to be achieved and the zoned-optimization model as the best method to accomplish the goal. In the following year, regulations were adopted and a ten-year timetable was established to achieve water quality goals. By 1973, the DRBC reported that 40 percent of the pollution sources along the estuary had complied with the regulations (5:587). The clean-up of the estuary is expected to be completed on schedule.

*A Model For the Allocation of Natural Environments Between Preservation and Development*

Fisher, Krutilla, and Cicchetti (3) developed a model which could predict a type of environmental cost other than pollution cost—the cost of irreversible transformation of natural environments. The model compared the alternatives of development or preservation of a natural environment on the assumption that each alternative would achieve its highest valued use, either by market action or government intervention. The model was designed to maximize the present value of net social benefits for an area and was given by the equation

$$\int_0^{\infty} e^{-\rho t}\left[B^P(P(t), t) + B^D(D(t), t) - I(t)\right] dt$$

where

$e^{-\rho t}$ = continous compounding over time at the social discount rate $\rho$

$B^P$ = excepted net social benefits at time t from P units of preserved area (represents opportunity cost of development)

$B^D$ = excepted net social benefits at time t from D units of developed area

I = capital investment cost at time t of making the transformation from preserved to developed (social overhead)

t = time

The constraint equations were:

$P + D = L$ where L is the fixed amount of land in the area under consideration

$P(O) = P_O$, $D(O) = D_O$ — the values of the existing preserved and developed areas (initial conditions)

$D = \sigma I$ where $\sigma$ is a constant (area/money) of irreversibility

$I \geq O$ to establish an irreversibility constraint in the model to correspond with the real world of environmental development.

The authors noted that if developments were reversible, then the problem of environmental losses would disappear and the model would not be necessary. An additional assumption of concave benefit functions for $B^P$ and $B^D$ was added so that returns to increasing preservation would be positive but diminishing.

The solution of the objective equation required the use of rather complex mathematics and is not repeated here. It is sufficient to note the results that were obtained. Two optimal development paths were found when the amount of land D was plotted over time. One path, D*(t) in Figure 2, assumed that investments could be reversed without costs.

The other path, D(t), was corrected to account for irreversibility. At points along the curve where D*(t) exceeded D(t), marginal benefits exceeded marginal costs. When D(t) exceeded D*(t), marginal costs exceeded marginal benefits. The authors concluded that it would be generally optimal to refrain from development *even when comparisons of current benefits and costs* indicated the economic feasibility of development if, in the relatively near future, reversibility of the investment in development was indicated by the model.

Application of the model to the Hells Canyon area of the Snake River placed additional restrictions of patterns of time variations of the benefits from development and preservation. The development proposed for Hells Canyon involved construction of a hydroelectric power site. The authors noted that traditional benefit estimates were based on analyses of current benefits versus costs without accounting for the decrease in benefits occurring over the life of a hydroelectric project. They believed that decreasing benefits would result from new technologies developed in the future which would make current power plants obsolete.

On the other hand, the authors concluded that the benefits from uses of preserved areas would increase over time as a result of increasing demands for recreational use of wilderness areas. They stated that as benefits from preservation increased relative to benefits from development, the optimal path of development would decrease, leading to the interpretation that development, if done at all, should be done immediately.

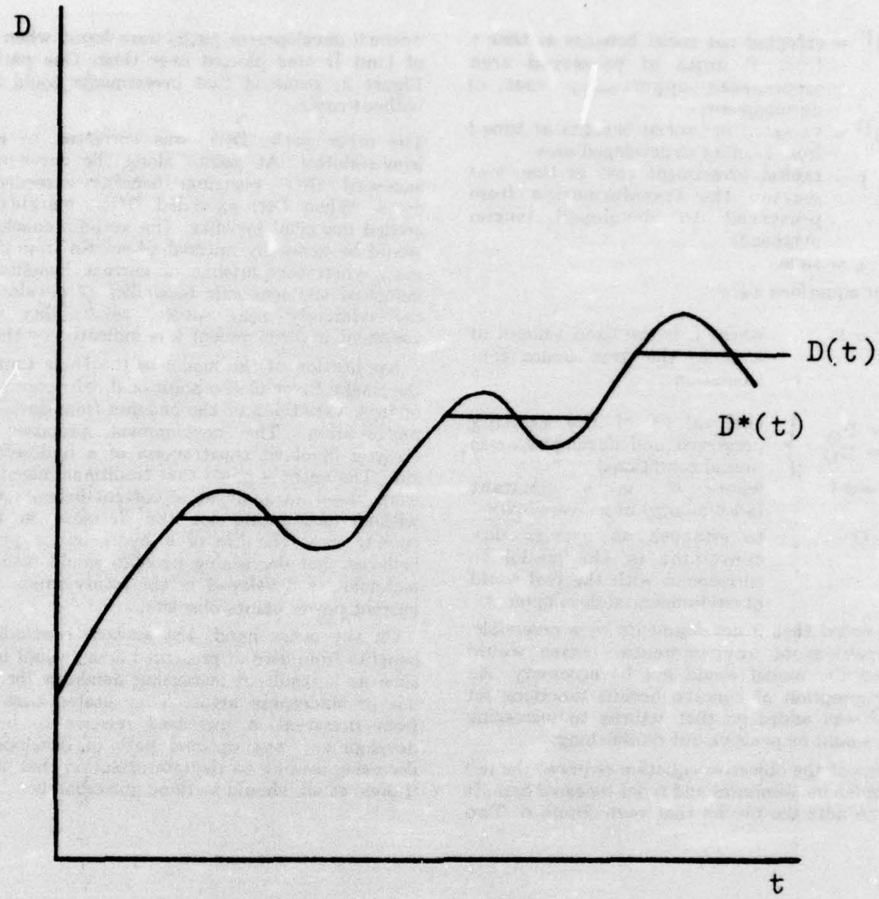


**Figure 2. Amount of Developed Land As a Function of Time—Short Run, D*(t), and Long Run, D(t), Paths.**

The rate of decrease of benefits from technological obsolescence was defined as the rate $\pi$, and the rate of increase in preservation benefits was defined as the rate $\phi T$. The authors then calculated the minimum benefit from preservation in the initial year which would cause the present value of preservation benefits to equal the present value of development benefits over the lives of both alternatives.

$$b_p{}^m = \sum_{i=1}^{T} \frac{b_O/(1+\pi)^t}{(1+i)^t} \Big/ \sum_{i=1}^{T'} \frac{\$1\,(1+\phi_T)^t}{(1+i)^t}$$

where:

$b_p{}^m$ = minimum initial year's benefit required to make the present value of preservation benefits equal to the present value of development benefits

$\bar{b}_O$ = the development benefit in the initial year

$\pi$ = rate of technological obsolescence measured in terms of decreasing benefits (percent)

T = terminal year for the development project

T' = terminal year for the preservation alternative

i = discount rate

$\phi_t$ = percent rate of growth in annual benefits derived from the preservation alternative.

Using studies conducted by state and federal wildlife agencies, the authors calculated the opportunity benefits which would be foregone if the hydroelectric project were developed. The first year's benefits from the project were calculated on the basis of the present value of annualized costs per kilowatt of generating capacity. The authors found that $b_p{}^m$ far exceeded the minimum value required and concluded that the Hells Canyon development should not be undertaken.

*Simulation of A Wilderness Area*

The model described in this section was developed to assist in the analysis of alternative policies of management of wilderness recreation areas. Developed by Smith, Webster, and Heck (16), it is an illustration of the type of model that could be used to estimate the

benefits to be derived from preserving wilderness areas. It could also serve as an aid, in a tradeoff model, in determining the land area required to accommodate a certain number of users. For a fixed wilderness area, it could be used to set a limit on the allowable frequency of use to maintain given environmental control standards relating to air, water, and land pollution.

The model was written as a computer simulation rather than in equation form. It simulated a network of trails and campsites used by parties of different sizes. The primary attribute measured by the model was solitude. The method of measurement was to keep track of the number of encounters between various parties in the simulated wilderness area.

The model was initialized by a schedule of arrivals to the wilderness area. Party arrival times, sizes, lengths of stay, and behavior within the area were assigned from probability distributions. These distributions were based on historical data provided by managers of wilderness areas. Two dimensions were selected to measure the intensity of an encounter between parties: Place and size of party. The rationale was that a person would experience less of an intrusion on his solitude if he encountered a party of one along a trail than he would experience if he encountered a party of four in his camp.

GPSS V was used to program and execute the model as a scheduling algorithm. The authors reported that the number of encounters each group experienced varied widely as use levels increased, although in most cases the differences for a particular group were significant at the five percent level as use increased. They concluded that use intensity could have a significant effect on the expected quality of a wilderness experience.

### *Kohn's Model of Labor Displacement and Air-Pollution Control*

An analysis of Kohn's model (7) is useful for two reasons. First, one can see how a complex problem can be formulated easily into a linear programming problem using matrix nation. Second, it illustrates a model which is used to quantify a factor which is often treated as an irreducible in a benefit-cost analysis—the effect of a proposed environmental control program on employment levels. However, full developmnent of the employment model involves economic considerations beyond the scope of this paper. Emphasis will be placed on the development of the basic model in matrix notation and in a linear programming format.

The situation to which Kohn's model applied involved a plan for controlling air pollution levels for a given region. The standards to be achieved were expressed in quantities of emissions per unit of source activity for a specific number of pollutants. Within the region were a number of pollution sources for which expected activity levels were given in terms of emission quantities per unit of activity for each of the pollutants for which standards were set. A given number of pollution control methods were available for use by the sources. The cost of dollars using each method was expressed in terms of dollars per quantity of emissions per unit of activity. In addition, a factor relating each control method to the amount of each pollutant removed by that method was specified. As an example, Kohn provided the following units:

1. Amount of pollutants produced—pounds
2. Unit of activity—gallon of fuel consumed by a bus, truck, or automobile

The problem was to find the least cost strategy for meeting the specified emission levels. For example, if standards were set for two pollutants in a region with four sources and three control methods, the problem could be expressed mathematically as follows:

Objective function: Minimize cost of air pollution abatement for the region

$$C_1 X_1 + C_2 X_2 + C_3 X_3$$

where $X_j$ = control method j (lb/gal)
$C_j$ = cost of control method j ($/lb/gal)
$j$ = 1, 2, 3

In matrix notation, the objective function would appear as

$CX$

where: $C$ was a matrix of cost coefficients,
$X$ was the solution variable vector.

Since the objective function was in terms of the variable X associated with the control methods, it was necessary to establish the total amount of pollution acted upon by each control method. Each source chose the control methods it desired to use to remove the amount of pollution it produced. If Sources 1 and 4 used all three control methods, Source 2 used methods 1 and 3, and Source 3 used Method 2, the following constraints could be written:

$$\begin{aligned} X_1 + X_2 + X_3 &= S_1 \\ X_1 \phantom{+ X_2} + X_3 &= S_2 \\ X_2 \phantom{+ X_3} &= S_3 \\ X_1 + X_2 + X_3 &= S_4 \end{aligned}$$

where $S_i$ = expected pollution activity of Source i (lb/gal)
$i$ = 1, 2, 3, 4

The above constraints could be expressed in matrix notation by defining a 0-1 matrix U whose elements $U_{ij}$ were equal to one if control method j was used by source i, and zero, otherwise. Thus,

$UX = S$ defined a constraint establishing the amount of pollution abatement per control method.

In this example, U would appear as follows:

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

An additional constraint was required to insure that the air quality standards were met. For a given pollutant k, the total abatement for all control methods must at least equal the required emission level $a_k$. Using the emission factors described earlier, the constraints were

$$\begin{aligned} E_{11} X_1 + E_{12} X_2 + E_{13} X_3 &\quad a_1 \\ E_{21} X_1 + E_{22} X_2 + E_{23} X_3 &\leq a_2 \end{aligned}$$

where $E_{kj}$ represented the emission factor of pollutant k, expressed as a percentage of abatement by control method j. In matrix notation,

$$EX \leq a$$

The entire cost minimization model in matrix form, as Kohn presented it, is shown below.

Obejctive function: Minimize CX
Subject TO: $UX = S$
$EX < a$
$X \geq O$

Given: L number of pollutants
M number of sources
N number of control methods

Where: $C$ = cost coefficient vector (1 x N)

$X$ = control method vector (N x 1) [solution variable]
$U$ = 0 − 1 matrix (M x N)
$S$ = source vector (M x 1)
$E$ = emission factor matrix (M x N)

The matrix model was in a form which was suited for solution by linear programming methods. The interested reader can refer to the literature (7) for a discussion of the extensions to the model used by Kohn to evaluate the effect of air pollution control methods on employment levels.

## CONCLUSION

The models presented in this paper are a very small sample of the number and types of models currently used to assist in benefit-cost analysis related to environmental pollution problems. An increasing number of models have been used in attempts to find optimal solutions to environmental problems in terms of an established objective. The optimal solutions, in some cases, have enabled decision makers to quantify factors which had formerly been treated as irreducibles in benefit-cost analyses of evironmental pollution control programs. Considerable work has been done, but the challenge to improve the existing models and to develop new models remains.

The following quote from a Water Pollution Control Federation report summarizes the challenge for control of all pollution—air, land, and water:

> Just as today's analytical techniques, treatment methodologies, and assessment capabilities all need upgrading to meet the challenge of higher expectations, so do current techniques for policy formulation need improving to deal with the complex and multiple social objectives associated with water quality systems.
>
> Such water quality problems are exceedingly complex. . . Early policy modeling efforts have generally over-simplified the problem so that manageable models might be obtained. More recent efforts have demonstrated a trend towards greater complexity as improved mathematical techniques for solving the models have become available. This trend does, presumably, lead to solutions that are closer to reality, but, inevitably, it also leads to models that are difficult for the decision maker to understand. The result is that sophisticated models are often not tried because potential users simply find them overwhelming.
>
> The ability to link a number of simple, readily understandable models to provide an overall solution that is realistic would be an important step forward. . . .
>
> Public policy in water pollution control may be characterized by many objectives, not all of which are compatible. A long-standing and well known shortcoming of optimization techniques is the requirement that the objective be stated in terms of a single measure. For most water quality problems, there is no way of expressing the various objectives in a common measure. Some efforts directed towards solving multiple objective problems have begun, but a great deal of additional work is needed. Until such work is completed, the process of rationally reconciling our economic and environmental goals will remain one of educated guesswork, a form of decision making that leaves few satisfied. . . .
>
> The objectives considered in current policy models are frequently micro-economic in nature, dealing with cost minimization or income maximization. On the other hand, the goals of decision makers often involve much broader concepts, including equity, income redistribution, and trade-offs between non-quantifiable entities that are frequently poorly defined. Perhaps the major research need for policy modeling is a clearer understanding of the links between technology and micro-economic phenomena on the one hand, and micro-economic, social, and ethical considerations on the other. Until policy models are able to consider such goals explicity, model use by decision makers will be severely limited (6: 250-251).

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# CHAPTER X — ECOLOGICAL EFFECTS OF WAR

## ECOLOGICAL EFFECTS OF WAR: VIETNAM

By Dannie O. Burk, Capt, USAF

*Introduction*

History has not maintained any detailed records of the environmental damages and long lasting effects of war. The Vietnam conflict is the first war to have this detailed analysis of the possible effects. This analysis to date has been conflicted and to a large extent biased to the point of view of the authors. This paper is written in an attempt to provide an objective look at the effects that war (in this case guerrilla warfare) may have on the regional ecology of Vietnam and possibly all of Indo-China. I am simply looking at the actions and their possible effects. In this study, the major assumption is that the desired state of the ecosystems discussed is the state in which the system was in prior to the commencement of military operations.

The article will present several of the general weapons types utilized in Vietnam with heavy emphasis on the herbicide operations and their possible impact. The herbicides are emphasized because they probably caused greater ecological change (damage) and because their long term effects are less known. A brief discussion of conventional weapons and land clearing operations (Rome Plows) is also included along with a limited discussion of some effects that can only be attributed to the combined effects of the weapons used.

### DEFINITIONS

Before proceeding further, I will provide a list of definitions that may be needed to help clarify some meanings.

*Herbicide*—Chemical compound which will kill or damage plants (14:222).

*2, 4-D-2,4-Dichlorophenoxyacetic acid*—Selective translocated spray and pre-emergency herbicide for broad leafed weeds (9:473).

*2, 4, 5-T - 2, 4, 5-Trichlorophenoxyacetic Acid* - Selective translocated spray for woody species (9:476).

*Picloram - 4-Amino-3, 5, 6-Trichloropicolinic Acid* - Translocated spray for perennial species (9:473).

*Cacodylac Acid - Dimethyllarsnic Acid* - General contact herbicide and desiccant (9:474).

*Defoliant* - Chemical that causes leaves to drop off plants (3:57).

*Desiccant* - Chemical that kills leaves of plants, leaves may remain on plant (3:57).

*Conventional Weapons - Nonnuclear weapons.* The term excludes all biological weapons and generally excludes chemical weapons except for existing smoke and incendiary agents and agents of the riot control type (14:116).

### HERBICIDES

*History*

The destruction of crops or foilage cover for defensive positions of the enemy is not new as a tactic of war. The Romans used salt to deny the uso of the land to the Carthaginians (17-2). The use of fire was, and still is, used to deny areas and crops to the enemy.

The latest chapter began in 1941 when the United States began classified military research to develop chemical agents (herbicides) for use as weapons of war. This search for chemical agents to destroy enemy crops and cover has led to much of the herbicide technology now used in agriculture (10:108). Throughout World War II, the research into chemical crop destruction agents continued and by June of 1945, the Army was prepared to recommend the use of ammonium thiocyanate, but political considerations stopped further study of this compound:

> "Ammonium thiocyanate sounded very much like cyanide, which everybody knows is poisonous. If we use this chemical, we would be accused of conducting poison gas warfare; therefore, . . . (16:113)."

The end of the war came before other herbicides could be developed, but a letter from George Merck to Secretary of War, Robert Patterson, stated:

> "Only a rapid ending of the war prevented field trails in an active theatre of synthetic agents that would without injury to humans or animal life, affect the growing crops and make them useless (10:110)."

The Army continued low key research on wartime herbicide compounds through the years. In the spring of 1959, a large scale test of a compound of undiluted butyl esters of 2, 4-D and 2, 4, 5-T was conducted on a four square mile plot at Camp Drum, New York. Examination of the area in 1962 revealed that, "In general . . . trees throughout the area were dead and the resulting improvement in visibility was almost 100 percent (16:13)."

The first military use of herbicides was in Malaysia (1948). The British used helicopters to dispense chemicals for controlled crop destruction (16:2).

It was not until 1961, at the request of the Vietnamese that the U.S. actually used herbicides in a wartime situation. The initial trails of defoliants were conducted along highway 15 from Bien Hoa to Cap Saint Jaques (70 miles). Then in November 1962, the first use was in destroying enemy crops. The herbicide usage increased from this point to a 1967 peak then was phased out in 1971 (16:40; 8:279).

I have been able to find no real argument about the effectiveness of herbicides as a tool or war. Table I shows an evaluation of the effectiveness of herbicides in improving the visibility in forested areas (1961). The uses of herbicides in Vietnam were divided into two broad categories—defoliation (used to improve visibility) and crop destruction (used to deny food to the enemy).

The purpose of the chemical crop destruction program was to deny food to the enemy. In this context deny "is used to mean actual deprivation and the process of making food more difficult and expensive to obtain (2:11)." The major effect of the program is the increased logistics support required to support the combatant (2:V). At the most it was calculated that the VC would need three percent of the Vietnam crops to be able to

survive. Since the VC lived off the people (VC produced approximately ten percent of their own food) any attempt to reduce the food supply to the VC would reduce the supply to the local civilians. Therefore, to reduce the supply to the VC, a reduction in the food supply to civilians in the country side is a requirement. This is one cause of alienation, indeed hatred, directed at the government. As a result of this alienation (in some cases up to 88 percent of the population) and the somewhat questionable results of the program, there has been disagreement over the military effectiveness of this portion of the herbicide program (2).

The overall military effectiveness of herbicide operations has not been the center of discussions. The major discussion has centered around the effects of herbicides on man and his environment and if Vietnam as a country can accept the possible ecological consequences of the damages caused by herbicides and conventional weapons.

TABLE 1

Technical Evaluation of Defoliation Results

| Criteria | Percentage Effectiveness Evaluation Made From | |
|---|---|---|
| | Air | Ground |
| Defoliation | 60-90 | 40-90 |
| Canopy Kill | 60-90 | 40-90 |
| Vertical Visibility | 60-90 | |
| Distribution of Defoliant | 30-80 | 10-80 |
| Horizontal Visibility | | 40-70 |
| Total Target Effectiveness | 50-90 | 30-80 |

SOURCE 16:4

*Ecological Effects*

Before assessing the effects that herbicides have had on the ecosystems, I will briefly describe what is known about the toxicity of herbicides and their persistence in soil and water. The three types of herbicide mixtures used in Vietnam were ORANGE, BLUE, and WHITE. Table 2 gives the quantities of each agent used between 1965 and 1971 and also the compounds the agents contain.

The toxicity of the agents is also shown in Table 2. For comparison, the same source rates malathion as having a low toxicity (10:26). The Midwest Research Institute (MRI) study (10) found that unlike DDT, the herbicides would not remain in or build up in the system of the animals or humans (10:192, 207). As a result, herbicides will not concentrate at any point in the food chain as has been shown for DDT. The MRI study concluded by stating, "the direct toxicity hazard to people and animals on the ground is nearly nonexistent (10:207)."

However, there were presistent reports of illness in both man and animals after spraying (11:169-173). Investigation by military medical personnel could establish no long term physical damage (11:169). It is possible that the reactions were allergenic but no definitive proof was offered that would support any reason for the apparent illness. In the late 1960's a contaminant was found in 2, 4, 5-T (contained in ORANGE). This contaminent was TCDD (8:281). TCDD has properties similar to DDT in that it will concentrate in the food chains and the compound has a high toxicity. A report released in 1970 also linked 2, 4, 5-T exposure to a high incidence of fetal deformity in mice and rats (11:168).

Following release of the report, the use of ORANGE was suspended in Vietnam (11:173). In a National Academy of Sciences (NAS) report (1974), no "conclusive" evidence linking herbicides and birth defects could be found in the data available from South Vietnam (8:288).

TABLE 2*

| Agent | Active Chemical | Millions of Gallons Used | Relative Toxicity** |
|---|---|---|---|
| ORANGE | 2,4-D<br>2,4,5-T | 11.22 | LOW |
| WHITE | 2,4-T<br>PICLORAM | 5.24 | VERY LOW |
| BLUE | CACODYLIC ACID | 1.12 | VERY LOW |

* 8:1
** 10:26

The persistence of herbicides in the soil and water of Vietnam was reported in 1968. As shown by the following quotes, the persistence of herbicides used in Vietnam is not considered to have long lasting effects on the soils.

> ". . . under tropical conditions in Vietnam, regulated areas treated with ORANGE at 3 or 6 gallons per acre show no residual effects of herbicides in soil after a period of several months . . . (15:5-D)."
>
> "From the limited data available, areas treated with WHITE show no toxicity to the most sensitive crops (Black Valentine Beans) twelve months after defoilant application (15:7-D)."
>
> "Cacodylic acid or agent BLUE is rapidly deactivated in contact with soils and causes no residual toxicity problems from the application rates used in Vietnam (15:7-D)."

In general, with the herbicides used in Vietnam, residues will not persist at phytotoxic levels in the soil for long periods (10:290).

The persistence of herbicides in water has not been studied as closely as it has in soils. Based on research conducted in the U.S., chlorophenoxyacetic acids (2, 4-D and 2, 4, 5-T ) they tend to break down and disappear in water. The rate is dependent on the quantity applied (10:226). Little can be said about picloram and Cacodytic acid because of the lack of research, but there are initial findings that indicate that sunlight tends to speed disappearance of picloram (10:226). Since very little is known about the amount of herbicides that are getting into the waters of Vietnam, the total effects on the water quality are not known (10:292). The same herbicides have been used in the U.S. to clear waterways and there were no reported ill effects. However, one must be cautious because of regional differences in the areas and the differences in concentrations (10:224-227).

"There is no question that the greatest short-term and long-term *direct* ecological consequence of using herbicides in Vietnam (or anywhere else) is the destruction of vegetation (10:290)." As might be expected, no one has questioned that there will be a major ecological

change caused by the use of herbicides, but the military is implying by the use of herbicides that the consequences of their use on the ecology is out weighed by the military advantages of the use of herbicides. Table 3 shows the extent of herbicide application in Vietnam.

The damage caused to crops is limited to the crop planted at the time of application and, as reported earlier, the land may be replanted (dependent on seasons) in several months. The drift of herbicide spray from the intended application area under maximum design conditions should not have been over two kilometers from the applications area. When drift did cause damage, claims could be filed that would reimburse the owner for damages encountered.

The inland and mangrove forest present a much greater problem in attempting to assess the ecosystem damages that have been caused by the herbicide application. Since mangrove trees are especially susceptable to herbicide damage, generally one application will kill all trees in the area of application. This means that possibly up to 36 percent of Vietnam's mangrove forests have been destroyed (see Table 3).

TABLE 3*

ESTIMATED ACREAGE SPRAYED

| Vegetation Type | Total Acreage Millions | Total Srayed Acreage | % of Total |
|---|---|---|---|
| INLAND FOREST | 25.91 | 2.67 | 10.3 |
| CULTIVATED LAND | 7.80 | .26 | 3.2 |
| MANGROVE FOREST | .72 | .26 | 36.1 |
| OTHER | 7.07 | .39 | 5.5 |
| TOTAL | 41.50 | 3.58 | |

* Source 8:283

A major worth of the mangroves is the supply of decaying leaves that the forest furnishes to the aquatic ecosystem of which they are a part (4:2). A limited comparative study completed in February of 1974 between the Rung-Sat Special Zone (defoliated) and mangrove forest in the Vung-Tau region (nondefoilated) indicated that the defoilation of the Rung-Sat Special Zone probably did not permanently damage the estuarian ecology of Vietnam. The Special Zone had a reduced variety of aquatic life compared to the Vung-Tau region which indicates some damage, although probably not permanent (4:117-120). It has been estimated that it will take 100 years for the heavily damaged mangrove forest to recover naturally and 20 years to recover with man's help (8:286). A problem that may prove to delay recovery in the Rung-Sat and all defoliated mangrove areas is erosion of silt that had collected around the roots of the defoliated trees now eroding as the roots rot and no longer assist in settling of the silt (4:119). This may delay the time it takes for the mangroves to re-establish. In the areas where the mangroves have been defoliated, there has been an increase in malaria carrying mosquitoes which prefer waters which are more exposed to sunlight (11:165; 8:289). The Vietnamese have also lost an abundant source of firewood and wood for charcoal (11:289). The fact that wood cutters will continue to cut the available mangroves will also tend to extend the recovery period.

The inland forests have received their share of attention also, but due to the complexity of these forests and the lack of previous study, very little can be said with certainty about length of recovery time if the forest ever returns to its original ecology. The rehabilitation ability of the forest depends on the damage done to the dominant and subdominant vegetation. If the combination of herbicides, bombing, and fires have eliminated the dominant and subdominant species, the chances are that bamboo, if present, will tend to establish pure stands. If no bamboos are present, grasses and scrub brush will tend to dominate (5:1-12). If the damage has been limited to the upper canopy, the damage will be similar to cutting of the mature trees for lumber and the forest will tend to return to the same type of stand of timber. In the forest the other regions, fire has generally the same final results as herbicide applications in that there is a clearing of the land and a new system generally takes over.

One additional item which will add some insight into the extent of the damage to the inland forest is the previous damage to the primary forest that was caused by "Ray" farming methods. This "slash and burn" farming has had a tremendous effect on the primary forest of Vietnam. As a result, the inland forest has been damaged and the secondary forest has taken over as much as two-thirds of the inland forest (1:27-29). As an example, over a few years the people of one village may destroy the forest within a 15 mile radius of the village (10:281).

It was estimated that between 500,000 and 2,000,000 cubic meters of commerically valuable timber has been lost due to herbicide operations. Additionally, between 6 and 12 million cubic meters of nonmerchandisable timber (food for firewood and charcoal) has been lost (1:29)—no small loss when considering the extend of use of wood for fuel in Vietnam.

The direct effects of herbicides on the animals as mentioned earlier are negligible, but the changes in the vegetation have tremendous effects on the ecosystem because of the changed habitat. This change can be both good and bad depending on which animals need the most help.

As an example, if the forests are destroyed, the Indo-Chinese Gibbon (endangered species) will either have to move to other forests or die because he is a tree dweller that feeds on foliage and insects and very seldom touches the ground. Whereas the Kouprey (an endangered bovine) will probably be helped due to increased browse production from developing bamboo and other grasses in the damaged areas (10:268-269). It has been found that moving to new areas will be very hard because in most cases, the jungle has been found to support just about the maximum life possible. The effect of herbicides on fish is essentially the same. In the herbicide operation removes (kills) the plant life of a selected type, this can cause problems for the members just above the plant in the food chain. The Tilapia (indigenous to Southeast Asia) has a rather limited diet and if the food was destroyed, it would have a deleterious effect on the fish (10:291). These are just two examples of the many that could emerge from the changed ecosystems which result from herbicide application.

## CONVENTIONAL WEAPONS

The use of conventional weapons have been on an unprecedented scale. It was estimated that in 1972, the

U.S. had exploded over 13 million ton of explosives in Indo China (17:21). One estimate of the area affected by cratering was 325,000 acres. These would add to the damaged area reported in Table 3 although there is probably some overlap. One result of the bombing has been a loss of revenue for the timber industry. It is estimated that some sawmills spent up to four hours a day repairing damage to saw blades caused by shrapnel imbedded in logs. Surprisingly enough, this loss of time and equipment was found to probably have the greatest impact on lumbering in the region. These losses are expected to continue for an indefinite period until the forest has been purged of all timber standing when the war was active. The fact that Vietnam has a signficant quantity of lumber remaining that could be used, even with the losses to herbicides, is not as important as the fragment damages (1:58). In addition, the entry of shrapnel into the tree leaves a wound which fungal rot may enter and destroy the tree. Rubber trees are especially susceptible to this problem (17:27).

Cratering of farm land reduces the quantity of arable land by eliminating that occupied by the crater from production. As the region is modernized, equipment will be used to fill the craters, but this has not been done to date. There is a possible health hazard caused by injuries to humans and animals caused by walking on the weapon fragments scattered around the crater (18:25). Other possible environmental consequences are the possible increase in mosquitoes as a result of a partially water filled crater (17:26).

## LAND CLEARING

The final weapon used in the war in Vietnam that created problems with the ecology is the "Rome Plow". This bulldozer clearing of the land has accounted for the denuding of over 750,000 acres. Again this land could have been included as part of the herbicide or crater areas of Vietnam. This type of land clearing also leaves the former forest area open for bamboo (weed) infestation, or soil erosion (13:119-122). The land cleared by plowing will probably revert to grassland, or in some cases, be used for farm land. This will probably speed up a process called laterization. Laterization is a process of hardening of the soil. The removal of potential organic matter and the resulting physical change that may cause the speeded laterization is accomplished by land clearing (10:281). Once complete, laterization will cause the land to be of little use in agricultural production or for any plant life. Man's role in the environment has been changed because of the war. Vietnam has historically been a rural society producing its requirements for food and exporting the excess. As a result of the war, many rural people have been forced into towns and cities (urbanization) without being provided the ability to survive in the cities. The remaining people in the rural areas were not provided the means to increase production and therefore there was a net reduction in production. Vietnam now must import food to survive. As an example of the urbanization, Saigon has grown from less than ½ million to approximately three million people in the last 25 years (6:297; 12:552).

An additional possible change that may occur as a result of destruction of vegetation is climatic changes. As an example, in regions cleared there may be an increased temperature and less rainfall. This has happened in other areas and is only a possibility in Vietnam, but with up to ten percent of the land cleared there is a possibility (10:292).

## CONCLUSION

The war has caused ecological changes in Vietnam. There have been estimates of damages ranging from almost total destruction of the environment to only limited impact. As indicated by the references cited and the discussion, there will definitely be an impact on the environmental quality. The extent of the change and whether the change will be for the better or worse can only be determined definitely by continued observation. Indications are that damages are not going to be as bad as predicted. The study should be continued, if possible, to give indications of the effects if the situation is encountered again.

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